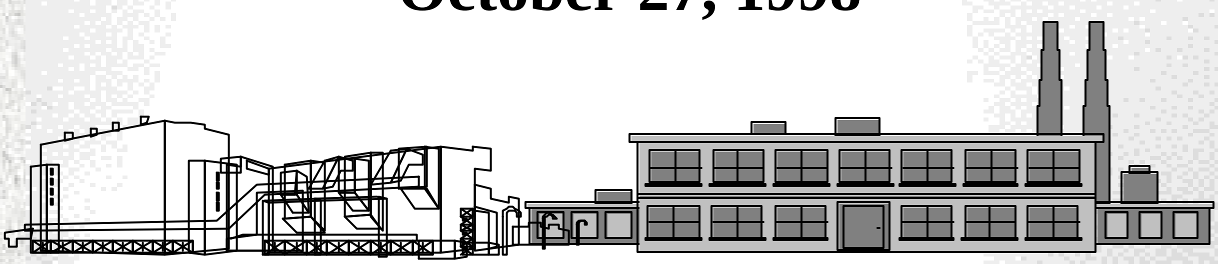
Process Readiness Review

Space Shuttle Program
Space Flight Operations Contract (SFOC)
United Space Alliance

An Independent Assessment of
SFOC/ USA-Ground Operations, NASA/SFOC Flight Operations, and NASA/KSC Safety & Mission Assurance

NASA Office of Safety & Mission Assurance
October 27, 1998



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Executive Summary

In July of 1998 NASA Administrator Daniel Goldin called for a review to "independently assess the readiness of both United Space Alliance (USA) and the NASA flight-critical processes to safely accommodate the increased flight rate at current staffing levels and skill mix." The assessment was initiated in response to staff reductions occurring in the USA workforce between January and July of 1998. The scope of this review included: United Space Alliance (USA) Ground Operations processes at Kennedy Space Center (KSC), NASA Safety and Mission Assurance (SMA) processes at KSC, International Space Station (ISS) processing activity at KSC, and USA Flight Operations processes at Johnson Space Center (JSC).

Ground Operations

<u>Work Control, Work Review and Change Control Processes</u>

The Ground Operations review team found clear, objective evidence of active and comprehensive work control processes, work review processes, and rigorous change control processes. The review team is convinced that these interlocking processes will serve to stop work in the event that insufficient numbers of qualified and certified workers are available to perform the work properly. The review team concluded that while staff reductions represent a constraint (along with facility and hardware limitations) to the amount of work performed per unit time, they do not pose a threat to quality and safety.

These conclusions are based and supported by an in-depth examination of USA/GO and NASA: 1) work control processes, 2) work review processes, and 3) change control processes.

<u>USA Ground Operations Future Capability and Manifest Demands</u>

The review team could not determine whether or not USA-proposed process improvements will achieve efficiencies necessary, in the time required, to support increased manifest demands in mid-to-late 1999. A deterministic/quantitative assessment at this time is not possible because of the following factors:

- Limited ability to confirm or accurately estimate implementation date for proposed efficiencies.

- Limited ability to confirm or accurately estimate the increased availability of workforce, resulting from proposed efficiencies.

- Limited ability to establish the risk associated with achieving efficiency goals or efficiency implementation dates.

- Incursion of unplanned and unscheduled work, particularly in horizontal processing (Orbiter Processing Facilities). It is noted that this is in large part driven by design-center Orbiter modification requirements, not defined at the Launch Site Flow Review, and the high maintenance required by critical Space Shuttle systems such as fuel cells, auxiliary power units (APUs), and the reaction control system (RCS). The high maintenance demands create scheduling uncertainty in ground operations and represent an additional, unquantified risk driver in terms of disassembling and reassembling hundreds of flight critical components to perform unscheduled maintenance.

- Uncertainties in manifest requirements.

- Lack of precision in definition of minimum baseline work-flow FTE requirements by skill or certification at the task execution level. Accurate "what-if" planning for future Space Shuttle manifest scenarios requires a knowledge base (currently unavailable) that provides "resource-loaded" task definition/decomposition, down to the individual task execution level. USA uses an estimate of 525,000 hours FTE for high level planning purposes for an average flow. USA/Ground Operations (USA/GO) recognizes the need for higher resolution and is working to refine resource-loading task profiles.

The team noted that opportunities exist to achieve efficiencies in administrative and management processes, which support the core work control/review and change control infrastructure. The strength of USA management leadership and commitment will determine the outcome.

In the event that planned improvements and efficiencies do not succeed, USA has contingency plans that offer short-term solutions. USA/GO has the capability and flexibility to address specific short-term staffing shortages through borrowing and lending certified skilled workers between facilities (i.e., among Orbiter Processing Facilities, the Vertical Assembly Building, and the Hazardous Processing Facilities). This practice can continue until the USA/GO system reaches saturation (e.g., three or four Space Shuttles in flow). Other contingencies include borrowing from USA/GO facility and infrastructure staff and possibly from parent company (Lockheed-Martin and Boeing) resources. If necessary, laid-off workers can be rehired and/or new employees could be recruited.

In any event, NASA management must closely monitor implementation of proposed USA process initiatives to assure that a stable infrastructure, capable of handling sustained higher flight rates, is developed. Flight safety will be assured as long as key ground operations processes remain in place. When the ground operations system becomes saturated it will be important to understand how "people in the process" (human factors) respond.

USA/GO Follow-On Review

In addition to the continuous monitoring by Space Shuttle Program (SSP) and Safety and Mission Assurance (SMA) organizations it will be necessary to conduct a focused follow-on review in six to nine months to quantitatively assess the status of USA process improvements and their effect on processing capability. This review will be contingent upon USA developing greater resolution in baseline resource-loading and greater maturity in risk assessment data.

NASA Kennedy Space Center - Safety and Mission Assurance

The role of this review team was to determine the ability of the KSC/SMA Office to support an increased flight rate of the Space Shuttle. In the past each division in the SMA organization had a significant pool of resources from which to draw to perform the activities requested by their customers. This resource pool was sufficient to allow extensive in-line support of the safety and quality functions at KSC. This resulted in a reactive mode of operation in response to requests for support by program offices at KSC, instead of a deliberate requirement assessment and resource planning activity. The transitioning of Space Shuttle ground operations to SFOC/USA, and the resulting reduction in personnel already implemented along with those planned by the year 2000, has forced the SMA organization into a state where planning is now a paramount necessity.

The review team began its activities by defining the interfaces and interactions between the KSC/SMA organization and USA. Activities following the interface definition were designed to understand the impact of changes from the SMA/Shuttle Processing Critical Process Team, and to baseline the KSC/SMA workforce for Shuttle processing. The final assessment area was to identify changes to the baseline requirements as a result of the critical processes, and additional efforts required by an increased flight rate. This would be compared with the current workforce allocations and assignments to determine if any gaps in the workforce numbers or skills existed.

Although no objective evidence was found to indicate that the work requirements would have any adverse impact on safety or quality, the KSC/SMA planning process is not sufficiently mature to provide evidence that the increased flight rate can be supported within current workforce ceilings.

It is recommended that the KSC/SMA organization notify the Office of Safety and Mission Assurance when it has completed the critical process definition effort and the workforce analysis planning. At that time a delta assessment will be performed to assess the completeness of the activity.

International Space Station (ISS)

The role of the International Space Station (ISS) team was to determine if there were any impacts on ISS processing of flight components from the proposed flight rate increase. The hypothesis was that ISS processing was the driver for the increased flight rate, and therefore would not be impacted by Shuttle processing. In order to test this hypothesis the review team met with both NASA Civil Service personnel and ISS processing prime contractor personnel. Discussions covered status of hardware, processing flow, manpower, safety issues, and projected schedules. Individuals were asked to identify any scenarios where the Shuttle processing for flight would have an adverse impact of the work being performed in processing of ISS hardware. It was clearly pointed out that the readiness and availability of payloads is what drives the Shuttle flight rate and there is no reverse impact. The current slack period of Shuttle launches was pointed to as an indication of that process. No objective evidence was found to indicate that Shuttle processing for flight would have any adverse impact of the processing of ISS hardware from either a safety or mission assurance perspective.

NASA and USA Flight Operations

The flight operations portion of the Process Readiness Review (PRR) performed a high-level assessment of the readiness of both NASA and Space Flight Operations Contract/United Space Alliance (SFOC/USA) flight-critical processes to safely accommodate an increased flight rate at the current staffing levels and skill mix. This review builds on the daily interaction of the SMA community with the Space Shuttle Program (SSP) and the SFOC/USA. In addressing the relative readiness of Flight Operations Processes, which are located at the Johnson Space Center (JSC), the Flight Operations Review Team had discussions with NASA Technical Management Representatives (TMRs) and SFOC/USA Associate Program Managers (APMs) for Orbiter Project, Systems and Cargo Integration Project, and Flight Operations Project.

<u>Orbiter Project</u>

The Flight Operations Review Team finds that Orbiter Project Team, comprising NASA, SFOC/USA and Boeing-RSS, are, with one exception, able to surge to a flight rate of eight flights per year. To gain the ability to sustain an increase in annual flight rate, the Orbiter Project Team must continue to manage the critical skills necessary meet the projected demand and augment critical skills with Boeing corporate resources as needed. A concern identified by the review team relates to the instances when multiple anomalies are presented in a single subsystem, as has occurred many times in the past. The SFOC/USA and Boeing-RSS team believe that they will be capable of supporting analysis and resolution of multiple anomalies in a single subsystem by accessing Boeing corporate resources; however, this capability has not yet been tested. In addition to the staffing challenges, the production of ET umbilicals must be made more efficient to meet a rate of eight flights per year and to extend beyond eight flights per year. Current production levels are just keeping pace with demand. ETs are being shipped from the Michoud Assembly Facility without installed umbilicals; an undesirable situation.

<u>Systems and Cargo Integration Project</u>

The current Systems and Cargo Integration analysis processes are the constraining factors that define the flight rate capability. The flight analysis template now in place can be anywhere from 18 to 24 months in length, depending on the complexity of the payloads and mission profile. This is clearly demonstrated by the fact that even though the FY 1998 and FY 1999 flight rates were at five flights, the overall integration workload did not decrease due to the long lead time needed to develop the integrated certification for each flight. Recent manifest changes have caused certain analyses to be scrapped and re-performed due to changes in seasonal conditions that affect both launch and on-orbit loads. Changes in assignment of payloads to different vehicles also cause analyses to be re-performed due to the subtle differences among the Orbiters. Additionally, analysis of Shuttle upgrades and Orbiter enhancements that have been proposed or that are in work require significant analysis to meet certification requirements. In summary, the Systems and Cargo Integration workload did not decrease commensurate with the flight rate and, in some cases, actually increased.

The Flight Operations Review Team finds that the NASA, SFOC/USA, and Boeing-RSS Systems and Cargo Integration Team is actively planning for the future and increased annual flight rates. This is demonstrated by initiatives, both implemented and in work, to reduce certification analysis cycle time and to increase the efficient use of the combined work force. The ultimate consolidation of the Boeing-RSS, SSP and ELV integration work force at the Boeing-Huntington Beach facility will enhance the capability to meet unplanned peaks and valleys in future manifests. The commitment by SFOC/USA to retaining critical skills is demonstrated by the budgeted Critical Skills Retention Fund and the continual management attention paid to this concern.

Flight Operations Project

The Flight Operations Review Team finds that the Flight Operations Project is planning for the future operations environment by re-inventing the way they do business. Of the projects reviewed, Flight Operations has a clear understanding of the critical skills required to perform their mission and has the process in place to offset attrition of critical skills in the future. The Flight Operations Project continues to have concerns about the instability in the manifest. Continual changes and delays of missions in the manifest results in inefficiency by requiring time-sensitive training to be repeated. With changes planned in Flight Operations processes through the re-invention effort, the Flight Operations Project should be able to increase their flight-rate capability.

Overall, the three projects assessed in the Flight Operations Review portion of the Process Readiness Review can support a manifest requiring a rate of eight flights per year. Challenges continue in the area of critical skill retention; however, each project has a plan in place that is actively addressing this challenge. Initiatives identified by each project address the need to go to a higher annual flight rate and hold promise for improved efficiency in the long run.

Flight Operations Follow-on Review

Members of the Flight Operations Review team will monitor, on a continuous basis, the readiness of the Orbiter Project, the Systems and Cargo Integration Project, and the Flight Operations/Mission Operations Directorate Project.

1.0 Introduction

A Process Readiness Review has been conducted to "independently assess the readiness of both USA and NASA flight-critical processes to safely accommodate increased flight rates at current staffing levels and skill mix." The review was initiated by direction of NASA Administrator Daniel Goldin in a July meeting with the Associate Administrator for Safety and Mission Assurance, Frederick D. Gregory and the Associate Administrator for Space Flight, Joseph Rothenberg.

The review objectives were outlined in a July 17, 1998, letter from Mr. Gregory to Mr. Rothenberg:

> "The scope of our review will focus on ground operations processes at Kennedy Space Center (KSC), but will also include a higher level review of flight operational processes at Johnson Space Center (JSC) and International Space Station (ISS) processing activity at KSC."
>
> "The review will be conducted using our previous January 1998 OSMA review as a baseline. The focus of the review will be to establish an in-depth understanding and visibility into those processes, which have been directly affected by staff reductions. The assessment objective is to determine whether or not those processes, at current staffing and skill-mix levels, are capable, stable, controlled, and adequate to support both a one-a-month (approximate) Shuttle flight rate and ISS processing."

<u>Scope</u>

The scope of this review focuses on USA Ground Operations and KSC/SMA processes. The review also includes a higher level review of USA Flight Operational processes at JSC and ISS processing activity at KSC.

<u>Assessment Approach</u>

The assessment uses a process-evaluation or process-based mission assurance approach. The review team employed standard assessment techniques including document review, interviews, discussions, briefings, and on-site observations.

<u>Review Team</u>

Dr. Peter Rutledge served as the review coordinator supported by the following team:

Ground Operations:	Lead: J. Steve Newman, supported by Stephen M. Wander and Claude S. Smith
KSC/SMA:	Lead: Charles E. Cockrell, supported by William Hill (also addressing ISS)
Flight Operations:	Lead: William Hill, supported by A. Miles Whitnah

<u>January 1998 SMA Review</u>

The current review is a follow-on to the January 1998 assessment that evaluated the safety implications of the proposed staff reductions. The fundamental concept that OSMA used as the basis for recommending acceptance of staff reductions was that flight-critical processes would be improved and modified to achieve efficiencies (effectively increasing workforce availability) without compromising safety. The January 1998 study concluded that USA may be able to accommodate seven to eight flights per year with implementation of process efficiencies. OSMA recommended that USA prepare and deliver a plan to SSP to achieve process efficiencies. The Aerospace Safety Advisory Panel (ASAP) concurred with this finding.

It was mutually understood that NASA would accept USA's proposed staff reductions provided USA would:

- aggressively plan and implement improvements,
- provide verification, and validation of the effectiveness of process efficiencies, and
- quantify residual risks associated with the process changes.

On-Site Data Acquisition

The Ground Operations and KSC/SMA teams conducted on-site KSC ground process evaluation and data gathering during the weeks of August 24, 1998 and September 15, 1998. The Flight Operations team conducted interviews at JSC on September 30 - October 2, 1998.

Report Structure

The review is divided into three primary areas of focus: USA/Ground Operations, addressed in Section 2.0, NASA/KSC Safety and Mission Assurance (KSC/SMA) addressed in Section 3.0, and NASA/SFOC Flight Operations discussed in Section 4.0. As discussed in the Executive Summary, quality and safety in ISS processing is not affected by Shuttle flight rate. Accordingly ISS issues are not explicitly addressed further in this report. Findings, conclusions and recommendations are provided within each major section. Each section is structured independently, reflecting the approach and assessment requirements of the individual review teams.

Terminology

The Space Shuttle Program (SSP) is organized by project element (e.g., Orbiter project, External Tank project, and Solid Rocket Booster project) including the "Launch and Landing" Project. NASA KSC is responsible for the Launch & Landing project. The principal contract for the Launch and Landing project is called the Space Flight Operations Contract (SFOC). United Space Alliance, Ground Operations (USA/GO) is the SFOC Associate Program Manager (APM) for KSC Shuttle Processing.

Manifest

It should be noted that the Space Shuttle manifest changed significantly over the course of the review. The manifest identified at the beginning of this review identified the need to migrate to a sustained flight rate over the next four-to-five years of approximately eight-to-nine flights per year, beginning in early CY 1999. This manifest was referred to as Revision D. Changes in the availability of certain International Space Station (ISS) elements resulted in additional changes in the manifest that moved initiation of the projected sustained flight rate to late CY 1999, at the earliest. Although this did not change the approach taken in this assessment, the team was fully aware that any process enhancements that were planned to support the increased demand incurred by the increased flight rate now have additional time for development and implementation.

Safety Defined

For the purpose of this report, safety is considered to mean "no unplanned loss of resources through prevention of mishaps and management of risk."

2.0 USA Ground Operations

2.1 Introduction and Background

The USA Ground Operations review team has sought to evaluate potential safety and schedule impact to management and engineering processes that 1) control touch-labor work, 2) review touch-labor work, 3) control changes to touch-labor work.

The team used a structured scientific approach to frame the review in terms of three working hypotheses:

> Working Hypothesis #1
>
> Reductions in the number of workers in Ground Operations will not affect the quality of work or safety of the vehicle because management processes exist, and are implemented, which assure work process fidelity, regardless of the labor pool size or composition.

Proving the first hypothesis requires an in-depth evaluation of Work Control (Section 2.2) and Work Review (Section 2.3) Processes.

> Working Hypothesis #2
>
> Changes in work processes (including implemented and planned initiatives) will not be allowed to compromise safety because management processes exist, and are implemented, which will assure continued work process fidelity.

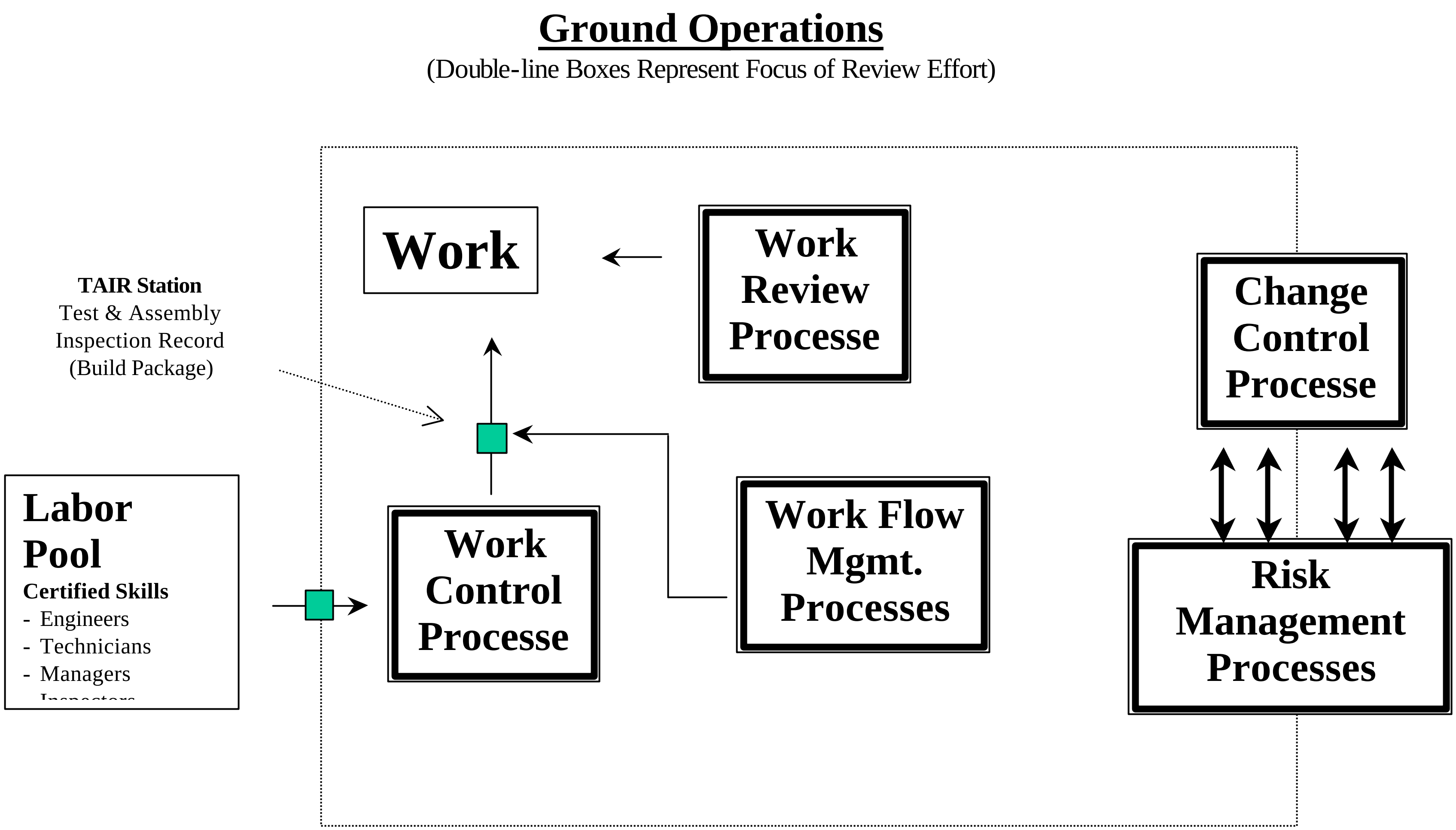
Proving the second hypothesis requires an understanding of Change Control Processes (Section 2.4) or "change gates" that assure that only fully controlled and carefully considered changes are implemented in either Work Control or Work Review processes. Change Control is considered to include formal and informal risk management, engineering review, and management review activities.

> Working Hypothesis #3
>
> Process improvements and efficiencies will be implemented in a fashion that will support increased manifest demands expected in mid - late CY 1999.

The third hypothesis, addressing the likelihood of proposed improvements meeting advertised goals (schedule and efficiency gain), is a complex task requiring "a best estimate" or "informed judgment," concerning both implementation dates and efficiency gains. The actual labor-hour demand per flow is not defined with high resolution and is subject to wide variability (up to 50% of work in horizontal processing cannot be predicted and is therefore unplanned or unscheduled). All of these topics are discussed in Section 2.5. The potential for any change to adversely affect Space Shuttle safety establishes the important linkage to the NASA/USA Change Control Processes. The fact that the Space Shuttle manifest is subject to change adds further complexity.

Figure 2.1-1 is a flow diagram depicting top-level relationships between flight-critical, touch-labor work, and the work control and work review processes that assure work fidelity and ultimately flight safety. These processes are enveloped by a line representing the change control and risk management processes that serve to insulate or protect work assurance processes from unwarranted or unsafe changes.

Figure 2.1-1 USA/Ground Operations Review Focus Areas



USA Ground Operations Roles and Responsibilities

The Ground Operations element is responsible for performing all ground processing operations for the Space Shuttle Program (SSP). These include:

- Stand-alone flight element processing
- Integrated vehicle processing
- Launch operations
- Landing operations
- Recovery operations
- Launch Processing System (LPS) operations, maintenance, and sustaining engineering
- Safety and mission assurance associated with ground processing operations
- Ground systems and facilities operations, maintenance, and sustaining engineering
- Facilities and ground support equipment (GSE) survivability projects
- Integrated Work Control System (IWCS) sustaining engineering

The USA Ground Operations organization and its subcontractors manage and execute ground processing operations (shown in Figure 2.1-2).

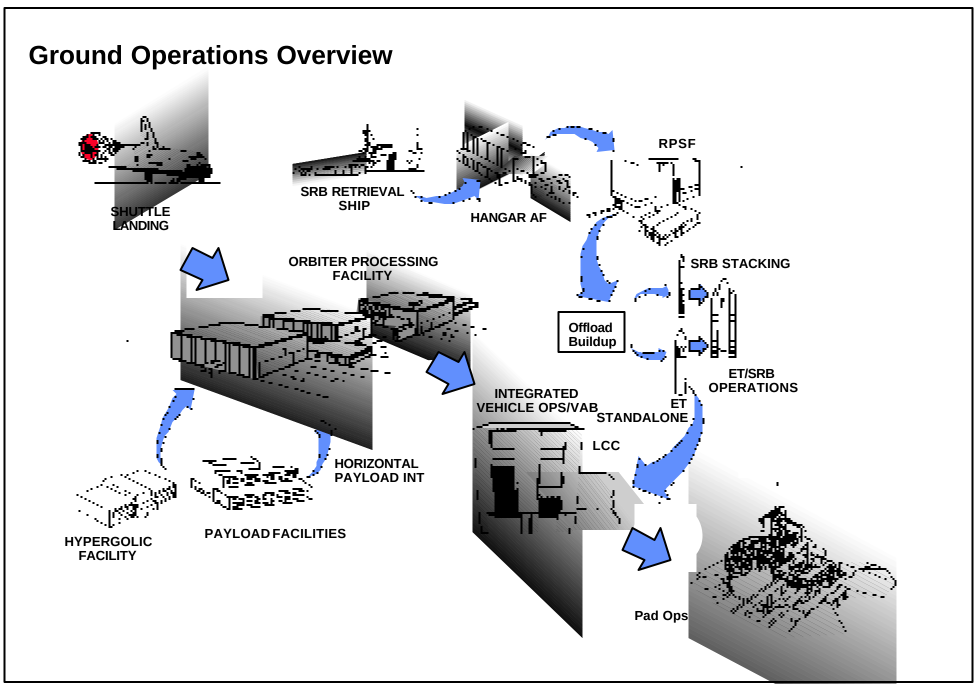


Figure 2.1-2 Ground Operations Notional Flow

Major Ground Operations Processes/Functions

SFOC/USA Ground Operations is responsible for providing task execution, direction, and control during daily processing activities, and employing trained and qualified personnel in support of the NASA launch team. The key USA/GO processes (shown in Figure 2.1-3) work together to accomplish Shuttle processing flow requirements and fulfill flow-specific Space Shuttle Program (SSP) requirements. The major processes that ensure flight elements, facilities, and ground systems are ready to support launch and landing are listed below:

- *Work Flow Planning:* Integrate all requirements for the creation, review, validation, and publication of flight element schedules that place demands upon resources.

- *Work Instruction Generation:* Create flight element processing work instructions for approved requirements and discrepancies.

- *Personnel Training:* Identify, develop, and deliver technical training to support launch site operations. Includes stand boards, proficiency boards, distance learning, On-the-Job Training, Just-in-Time Training, Kepner-Tregoe Instruction, continuous improvement, university programs, and vendor training.

- *Parts, Material, and Services Provisioning:* Execute interrelated processes to provide parts, material, and contracted services to launch site operations (excludes requirements definition).

- *Facilities and Support Equipment Maintenance:* Maintain certified, calibrated, and validated support equipment required to execute processing tasks.

- *Processing Task Execution:* Implement flight element processing requirements.

- *Processing Information Provisioning:* Develop, implement, and sustain computer-related products and services to maximize efficiency through automation.

- *Surveillance (recently renamed Assurance):* Assess the health of launch site operations from an independent contract compliance, quality, and safety perspective (excludes self-audits).

- *Requirement Control:* Identify approved program and project element flight and ground requirements for implementation by Ground Operations.

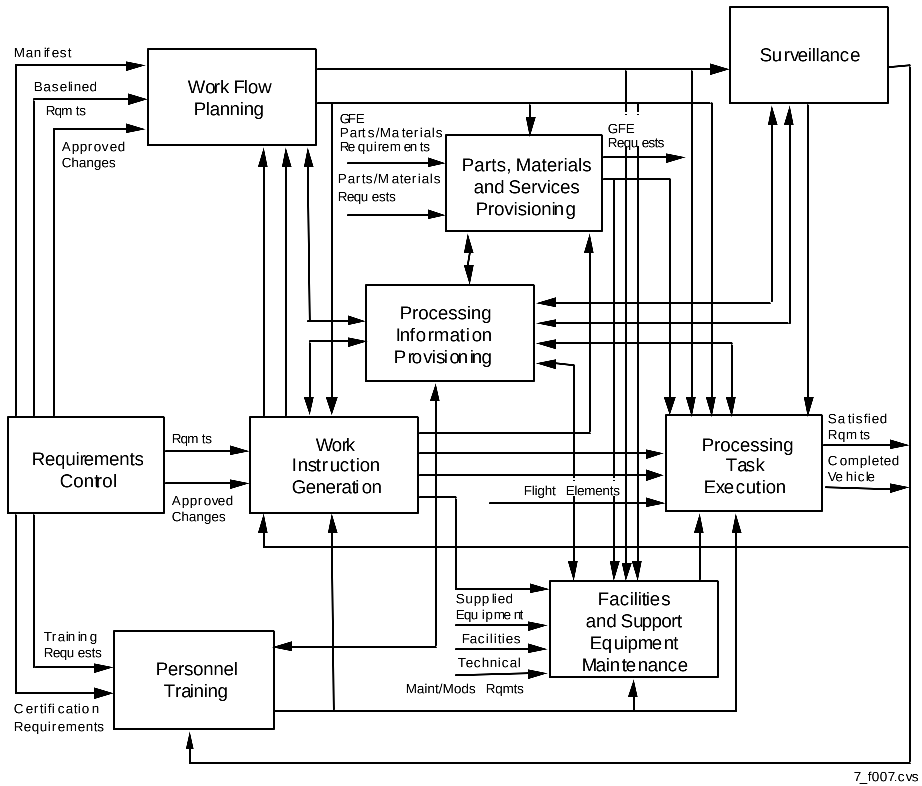


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Figure 2.1-3 Ground Operations Process Flow

Other Ground Operations responsibilities include:

- Manifest assessment
- Plans and schedules
- Released and approved procedures
- Requirements verification
- Readiness reviews
- Open item reviews
- Metrics and analysis
- Troubleshooting plans
- Anomaly resolution
- Contingency/emergency procedures
- Ground systems and facilities maintain, operation and validation
- Engineering for ground systems and facilities
- Processing status

- Configuration management (GSE, vehicle, and facilities)
- Closed-loop accountability
- Test and launch operations

Matrixed Certified-Skilled Labor Pool Approach

Ground Operations uses a skill-based resource management approach that interfaces with the integrated work control system to plan and implement specific work tasks. Resources are matrixed to the element flow managers, who are accountable for ensuring tasks are scheduled to support defined flow milestones. The Ground Operations test team supports real-time schedule execution under the direction of the chief test conductor, who is accountable for execution and management of the daily schedule while ensuring safe and efficient processing (See Figure 2.1-4).

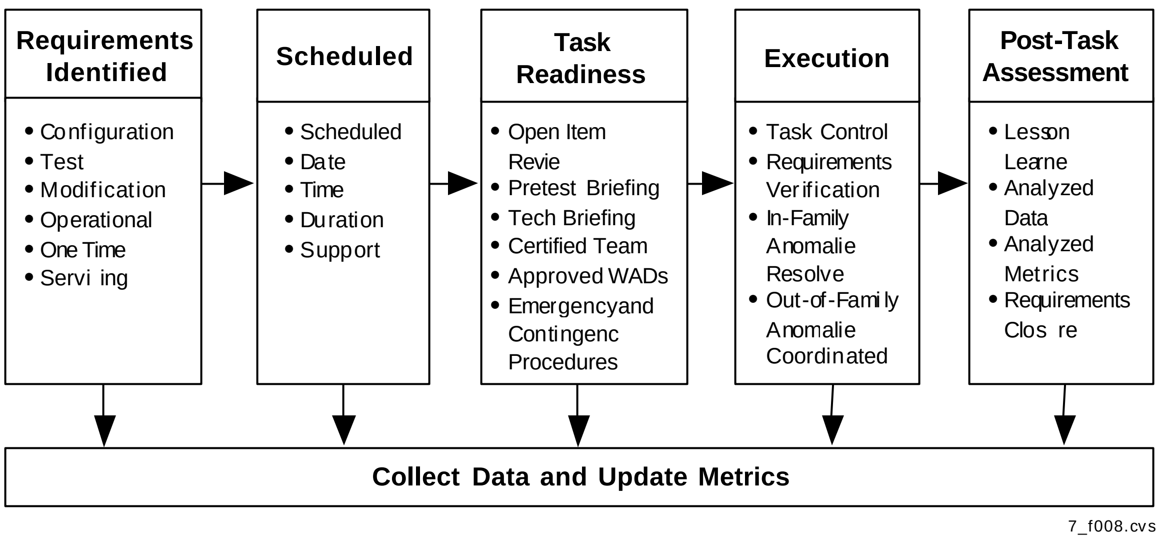


Figure 2.1-4 Task Execution Sequence

Recent Staff Reductions in USA Ground Operations

This review was set in motion by reductions in the USA workforce in response to NASA SSP resource constraints. Staff reductions were implemented in cases where no other alternatives existed. Specifically, the reduction in headcount from January to July of 1998 included 552 full time employees in USA Ground Operations. The 1998 reduction represents approximately 12% of the 1997 average USA Ground Operations headcount. A breakdown of the 552 FTE reduction is shown in the table 2.1-1.

Table 2.1-1 Recent USA Florida Staffing Reductions: Ground Operations

	Self	*Involuntary*		*1 Jan - 3 Jul 98*	
	Nominations	Layoffs	Sub-Total	Normal Attrition	Total
Exempt					
Managerial	19	1	20	5	25
Engineering	32	28	60	32	92
Computer Science	14	4	18	12	30
Other Professional*	29	49	78	14	92
Non-Exempt					
Shuttle Technicians	31	53	84	10	94
Shuttle Inspectors	8	14	22	5	27
Tile Technicians	1	32	33	3	36
Other	17	31	48	6	54
Union	36	49	85	17	102
Total	187	261	448	104	552

* *Other Professional*
Project Leaders
Business Ops Staff
Technical Ops Staff
Ops & Proc

NASA KSC Ground Operations Roles and Responsibilities

The NASA KSC Shuttle Processing Directorate (Code PM) provides direct management of launch countdown and landing activities, provides technical and operational insight into contractor processing activities, and manages the integration of facility institutional support for launch, landing, and ground processing operations. The organization structure is outlined in Figure 2.1-5

Specific responsiblities include:

- Technical Management Representative (TMR) for the Space Shuttle Program (SSP)
- Management of the development, certification, operations, and maintenance requirements of ground systems/facilities
- Government acceptance of the contractor's stand-alone processing activities through technical and operational insight
- Insight into vehicle integrated test, checkout, and servicing
- Management of launch, landing, and recovery execution
- Integration of institutional support to the program.

The Shuttle Processing Directorate maintains technical and operational insight of the contractor's work on behalf of the SSP and the hardware elements.

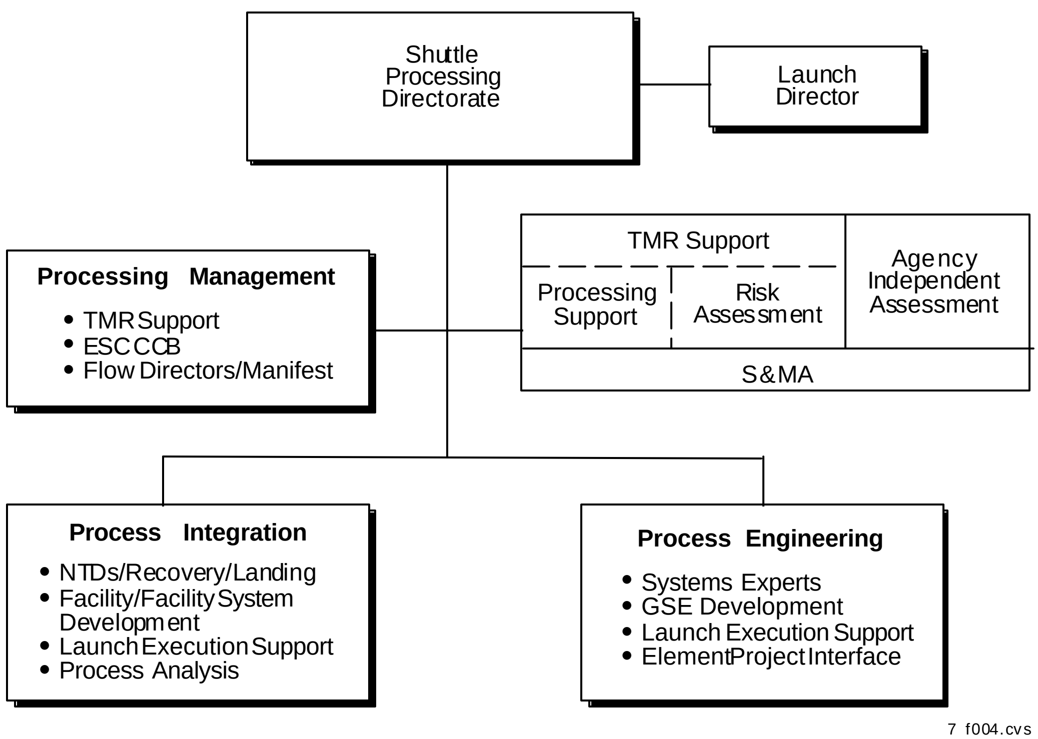


Figure 2.1-5 NASA KSC Organization

2.2 Work Control Processes

<u>Working Hypothesis #1</u>

Reductions in the number of workers in Ground Operations will not affect the quality of work or safety of the vehicle because management processes exist, and are implemented, which assure work process fidelity, regardless of the labor pool size or composition.

Space Shuttle safety depends on manufacturing and operational processes which are "capable, stable and under control." This is one of the fundamental doctrines of the NASA program management and safety and mission assurance communities. This section identifies and assesses those processes in-place at Kennedy Space Center (KSC) which assure that work is done by experienced and qualified people using capable and stable processes operating under control. Figure 2.2-1 is a flow diagram that shows the fundamental elements in the overall Space Shuttle ground operations work control process.

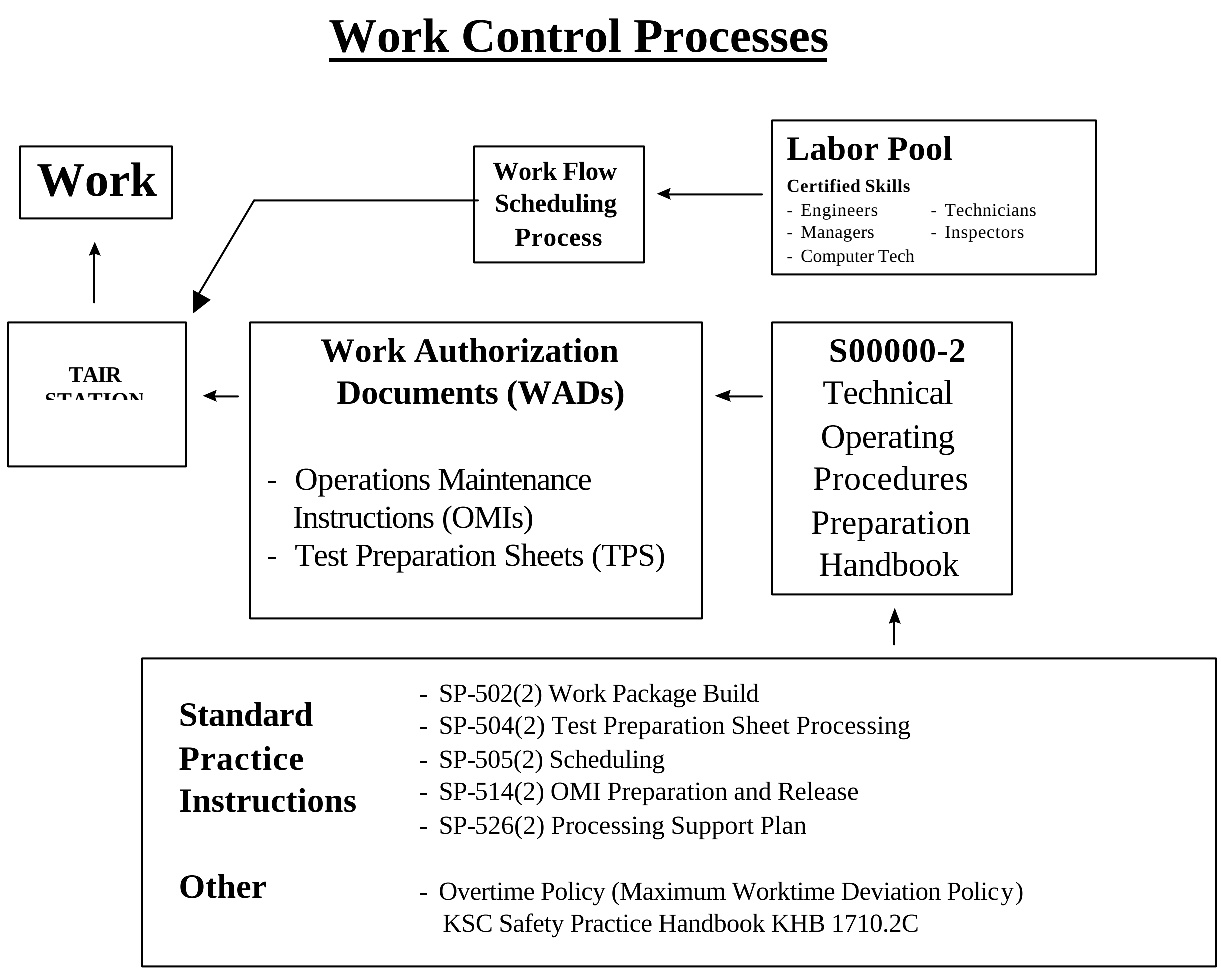


Figure 2.2-1 Work Control Notional Flow

The Ground Operations (GO) review team conducted the following on-site reviews, related to work control processes:

- Evaluated (document review and USA provided briefings) work control document chain including SPI, S00000-2, Technical Operating Procedures (TOPs), Work Authorization Documents (WADs), Operations and Maintenance Instructions (OMIs)
- Evaluated specific OMIs for Orbiter Processing Facility (OPF) Rollout and Solid Rocket Booster (SRB) Stacking
- Interviewed Task Team Leaders, Pad Leaders, technicians, and engineers
- Attended OPF High Bay-1, mid-body shop KICS (Kennedy Integrated Control Schedule) meeting
- Evaluated flow management processes and work schedule implementation at the task team level.
- Interviewed personnel in OPF, Launch Control Center (LCC), Vehicle Assembly Building (VAB), Hypergolic Maintenance Facility (HMF)
- Reviewed Product and Process Integrity/Continuous Improvement (PPICI) activities devoted to assuring work process fidelity

2.2.1 Standard Practice Instructions (SPIs) and Work Control Policies

USA/GO uses SPIs to assure consistent application of policies and procedures and to define NASA and other interfaces required to manage identified tasks and processes. SPIs are foundation work practice documents are used in the development of TOPs, WADs and OMIs. The GO review team evaluated many of the SPIs listed below (identified by USA/GO and NASA/KSC GO) and can attest to the rigor and detail of the work control documentation.

- SP-006(2) Task Team Leadership
- SP-502(2) Work Package Build
- SP-504(2) Test Preparation Sheet Processing
- SP-505(2) Scheduling
- SP-514(2) OMI Preparation and Release
- SP-526(2) Processing Support Plan

Vol IV: Facilities

- SO-007(4) Preparation and Processing of PMAR
- SO-010(4) Facility O&M Service Support and Work Authorization
- S0000004 VAB Processing

Vol V: Integrated Data Systems

- LP-001(5) Integrated Data Systems Intermediate/ Depot Level Maintenance Operations
- LP-002(5) LPS Central Data System Software Installation Operations
- LP-034(5) LPS CDS Control Room Operations
- LP-311(5) Personal Computing Resources Control and Use
- SP-306(5) LPS Build Handling and Processing
- SP-304(5) IDS Documentation Development and Maintenance
- SP-318(5) SCAN Data Base Update, Maintenance and Control

<u>Work Control Policies</u>

Overtime Policy (Maximum Worktime Deviation Policy), KHB 1710.2C

2.2.2 Technical Operating Procedures (TOPs) and Work Authorizing Documents (WADs)

Technical Operating Procedures (TOPs)

Documents that authorize work are called TOPs. A WAD is a TOP derivative applicable to a specific work package (i.e., specific Space Shuttle in process). The TOP/WAD management processe assure that ground operations work is carried out by teams consisting of the proper skill-set (individuals with appropriate training and/or certifications), using the proper tools, with the appropriate calibrations.

One of the USA process improvement initiatives is to develop an automated WAD development system called WAD Authoring and Validation Environment (WAVE). The WAVE objective is to establish a Universal Technical Operating Procedure (UTOP) system to be used for all TOPs, addressing both planned and unplanned work.

Work Authorization Documents (WADs)

WADs vary from 50 to 600 pages each, providing detailed instructions and requirements for the safe and successful implementation of the processing activity. WADs must be written and approved prior to the start of work. In addition WADs must be archived to document the work that was performed. The family of WADs includes:

- Operations and Maintenance Instructions (OMIs), pre-planned work authorization documents;
- Test Preparation Sheets (TPS),
- Work Disposition Documents which are used to close out Problem Reports, Nonconformity or Discrepancy Reports and;
- Work deviation authorization documents, necessary to address real-time changes to pre-planned work.

There are over 5,000 OMIs defined for ground operations processing at KSC. Any individual (Orbiter mission) processing flow may involve 2,000 planned WADS, derived from approved OMIs. It should be noted that in the horizontal processing arena (Orbiter Processing Facilities) it is not uncommon to have approximately 50% of the work planned, and 50% of the work unplanned, that is, the result of modifications, change requests, or unplanned maintenance including in-flight anomalies (IFAs). As shown in Table 2.2-1, any individual WAD identifies the number of highly trained and skilled individuals, with the appropriate certifications necessary to perform any specific task. WADs serve as foundation safety documents, incorporating lessons learned and risk management/mitigation requirements throughout. *Potential changes to WAD requirements represent a situation where instability or incapability for performing an operation may arise and is therefore a very real concern.* This concern brings strong focus to the need for maintenance and monitoring of existing change control processes.

WAD Authoring and Development

A documented process exists that governs the development of TOPs. This process is set out in S00000-2, “Technical Operating Procedures Preparation Handbook.” This 700 page, two-volume document serves as a handbook for the development of TOPs. S00000-2 references numerous Standard Practice Instructions (SPIs) which define fundamental technical and management processes and procedures for doing work at KSC.

WAD Release Process

The Test and Inspection Record (TAIR) station serves as the final step used to translate a TOP into a WAD, a vehicle/flow-specific authorization to do work. The TAIR station assembles released TOPs into a work build package (as shown in Figure 2.2-1). The step serves to tailor the generic work instructions contained in a TOP to address the special and unique needs of the particular vehicle in flow.

WAD Personnel Requirements

The WAD governs the skill set required to perform work. For example, Table 2.2-1 shows the skill set requirement for a typical WAD, an OMI for Orbiter roll-out from the Orbiter Processing Facility (OPF). The terms "Essential Personnel," "Maximum Allowable," and/or "Resource Loading" are used in different cases to represent *upper limits* on the number of individuals permitted for a given operation. This limitation is based on worker safety constraints, bounding the number of individuals exposed to a hazardous operation. *The terms do not represent the minimum number of individuals in each critical skill area necessary to do the job right.* The review team was told that the job, shown in the example below, could be conducted with less than 18 mechanical technicians, but noted that the minimum number had not been formally documented. It was noted that a minimum number of technicians may be implied in the details of the work-step instructions in many cases.

Example: OMI S5023.001, Section 1.6.2

> "All personnel utilized during actual Orbiter Lifting/Mating operations, such as controllers and coordinators, must be in direct communication with each other. Lifting operations will cease if direct communications are interrupted and will remain so until direct communications are re-established."

Table 2.2-1 Essential Personnel (OMI #S5023.001, Task Seq 04-003, ORB Transport Operations)

Title	**SFOC**	**NASA**	**BNA**	**BOC**
Move Director	1			
Test Conductor	2	1		1
Mech Tech	18			
Handling Engineer	2	1	1	
Quality	4	3		
Safety	1	1		
Facility STM	1			
OTS Techs	10			
OTS Eng/Sup	1	1		

Legend

SFOC: Space Shuttle Flight Operations Contractor
BNA: Boeing North American
BOC: Base Operations Contractor
ORB: Orbiter
OTS: Orbiter Transport System

2.2.3 Work Flow Planning

The following paragraphs have been abstracted from "Planning, Scheduling, and Readiness Processes for Shuttle Ground Operations," Document Number: OPPS-RD-97-001 Rev. C. The purpose of this section is to describe the role of work flow planning as an embedded work control process, that incorporates rigorous requirements documentation, control, and review, leading to the deployment of appropriately staffed task execution teams. The evolution and control of work requirements from inception through task execution and documentation is evident in the text abstract contained in the following boxed section.

Planning, Scheduling, and Readiness Processes for Shuttle Ground Operations

Launch Site Requirements Review (LSRR)

60 days prior to estimated arrival of the Orbiter at the OPF, a Launch Site Requirements Review (LSRR) is conducted by the Program Requirements Change Board (PRCB) to baseline the OMRS requirements and discuss proposed vehicle modifications and special requirements. Any changes that arise during or subsequent to the LSRR are approved and later presented at the Launch Site Flow Review (LSFR).

Launch Site Flow Review (LSFR)

30 days prior to estimated arrival of the Orbiter at the OPF, the PRCB conducts the LSFR to perform a final review of flow requirements. OPF flow milestone charts and the integrated assessment summary schedules for all flight elements associated with the mission are presented. Any changes resulting from the LSFR are incorporated within six working days of the LSFR and the approved Detailed Assessment schedule is baselined and annotated to reflect any changes.

Delta LSFR

The Delta LSFR provides an opportunity to incorporate any additional requirements that have been derived from (very recent) flight experience, such as In-Flight Anomalies, and non-standard tile damage.

Flow Task Plan (FTP)

The Flow Task Plan (FTP) development process begins approximately 90 days prior to the estimated arrival of a specific flight element (i.e., Orbiter, External Tank (ET), Solid Rocket Booster (SRB), Orbiter Maneuvering System (OMS) Pod, etc.) at KSC to begin its processing flow. Flight element system engineers work closely with flow planners to ensure that the FTP includes all the tasks necessary to meet the OMRS requirements for the mission.

Processing Support Plan (PSP).

60 days prior to estimated arrival of the Orbiter at the OPF, the first preliminary report listing the stand-alone FTP work tasks (referred to as "parent" tasks if they call out subordinate tasks such as Job Cards) is published and distributed for review. This report is called the Processing Support Plan (PSP). A separate PSP is produced for each flight element (Orbiter, ET, SRBs, Mobile Launch Platform, Launch Pad, and Main Engine Set).

Test and Assembly Inspection Record (TAIR)

Baselining of the Flow Task Plan (FTP) allows resource staging processes to commence (e.g., building of the work packages, gathering of parts and materials, developing of Test and Assembly Inspection Record (TAIR) work package indices).

Abstract (continued)

Kennedy Integrated Control Schedule (KICS).

The baselined Detailed Assessment schedules are the drivers for the individual element and site work Implementing schedules called the Kennedy Integrated Control Schedule (KICS). The KICS depicts a 96-hour/11-day window and includes the baseline Detailed Assessment tasks and emergent (also referred to as “unplanned”) tasks that meet specified criteria. The KICS schedule is published daily, Monday through Friday. The edition published each Monday through Thursday contains only schedules and support directly related to Space Shuttle processing operations. In addition to the KICS 96-hour/11-day pages, Mini schedules, when required, and support pages are included to provide greater detail of time and task definition on any KICS line-item and to identify the external support requirements (i.e., support provided by organizations other than those directly involved in Shuttle processing operations) as well as the specific times during the task that such support is required.

Deconflicting

The work implementing schedules are reviewed, and any conflicts discussed, at daily scheduling meetings. These meetings are devoted to reviewing processing flow activities scheduled in the 11-day window. Schedule progress is assessed each morning and schedules are adjusted prior to the start of first shift. Routinely, potential schedule conflicts between OPF bays and other processing sites are discussed to deconflict operations as much as possible and to best meet planned milestones. Schedule changes driven from these deconflictions are incorporated and disseminated in near real-time. For those conflicts which are more complex and cannot be resolved in the morning schedule meetings, splinter meetings are subsequently convened and final decisions relayed to the Daily Launch Operations (DLO) meetings which are held toward the end of first shift. Required changes are incorporated in the schedule and published in the KICS “Bulldog” edition prior to the start of second shift, daily.

Task Readiness

This process, which ensures that the execution of a task can begin as scheduled, verifies the physical staging of parts and materials, GSE, the work instructions for performing the task, and, where applicable, constraints lists. The physical staging process includes the gathering of specified resources, their transportation to a designated area at (or near) the work site, and the verification that the resources have, indeed, been staged and meet all requirements prior to the scheduled start of the task that they support.

Task Execution Control

As the scheduled start dates of tasks that are “ready-to-work” enter a specified time frame, they are downloaded into the Task Execution Tracking database which provides a list of all tasks available to a specific processing shop in a particular area. A customized queue of tasks to be worked by a processing shop is created prior to the start of a shift. The queue provides a list of all tasks planned to be accomplished by the shop on the specified shift.

Task Closure

The Task Tracking database is used to maintain the status of actions necessary for closure of the work instructions. Upon completion of the closure process, the task status is updated in the Task Tracking database and transferred to the Documentation Accountability and Control databases.

2.2.4 Personnel Management in Critical Work Processes

Work flow planning links are critical to assuring that the right number of individuals is present to perform critical tasks. Each morning, at 6:45 am, a Tie-In meeting takes place for the first shift of the day. This meeting serves to balance and define the day's work across various facilities. The tie-in meeting confirms that people, parts, and paper will be in place to support the day's planned activities. The review team noted that work flow/work scheduling is a process of negotiation and trading amongst first line managers under the orchestration of the Pad Leaders, who serve as work coordinators. The inter-relationships between key elements in this process are shown in Figure 2.2-2. (Note: FVOC = Floor Vehicle Operations Chief, OTS = Orbiter Test Conductor)

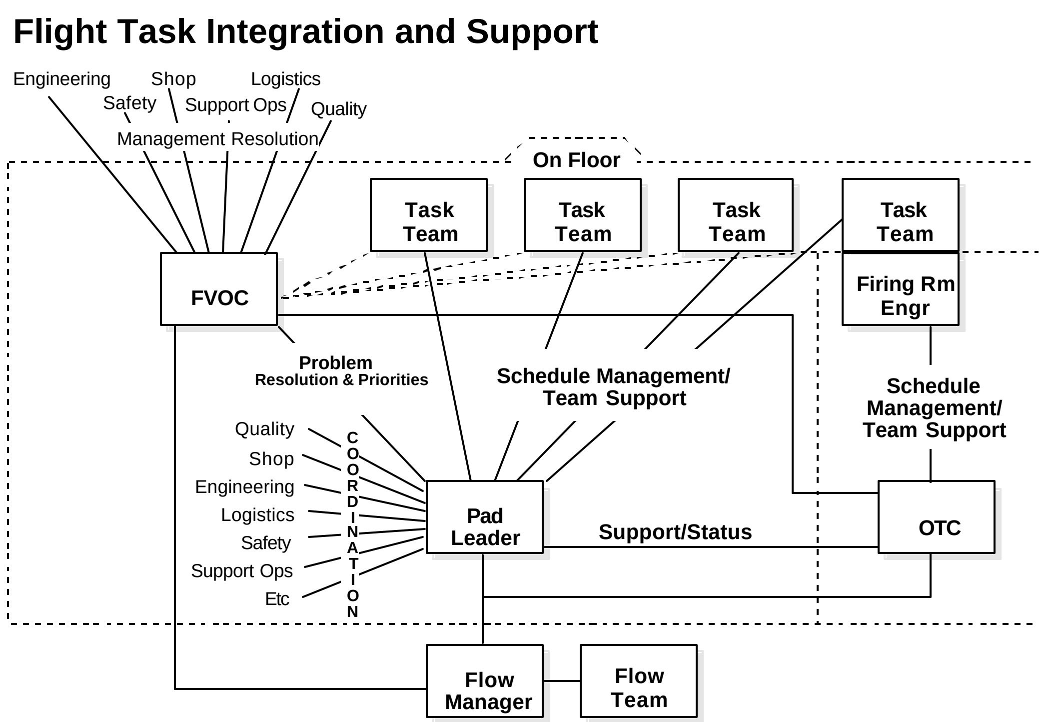


Figure 2.2-2 SFOC Work Implementation

<u>WAD Pre-Operational Briefings/Kennedy Integrated Control Scheduling (KICS) Meetings</u>

The review team participated in an early morning KICS meeting for the Orbiter mid-body team. The early morning meeting serves as the operational forum for reviewing and metering work assignments at the floor level. The KICS meeting uses an eleven-day moving window to discuss upcoming work content and define the specific work scheduled for the day. The KICS meeting is also an embedded risk management forum in which the team leader determines that he/she has the resources necessary to move forward with the scheduled work.

Critical Role of the Test Conductor

The Test Conductor employing his/her experience and judgement has the authority to move ahead with a given operation with less than the number of individuals explicitly identified in the OMI. The process is informal and does not require formal documentation although many test conductors do make log entries which might include decision rationale. It should be noted that "test conductor judgement" incorporates years of experience and knowledge. A typical Test Conductor has the following experience: BS degree in science or engineering, plus a minimum of ten years experience in operations and test team leadership. A Test Conductor would typically be simultaneously coordinating the activities of multiple Operations Task Teams (see Figure 2.2-3).

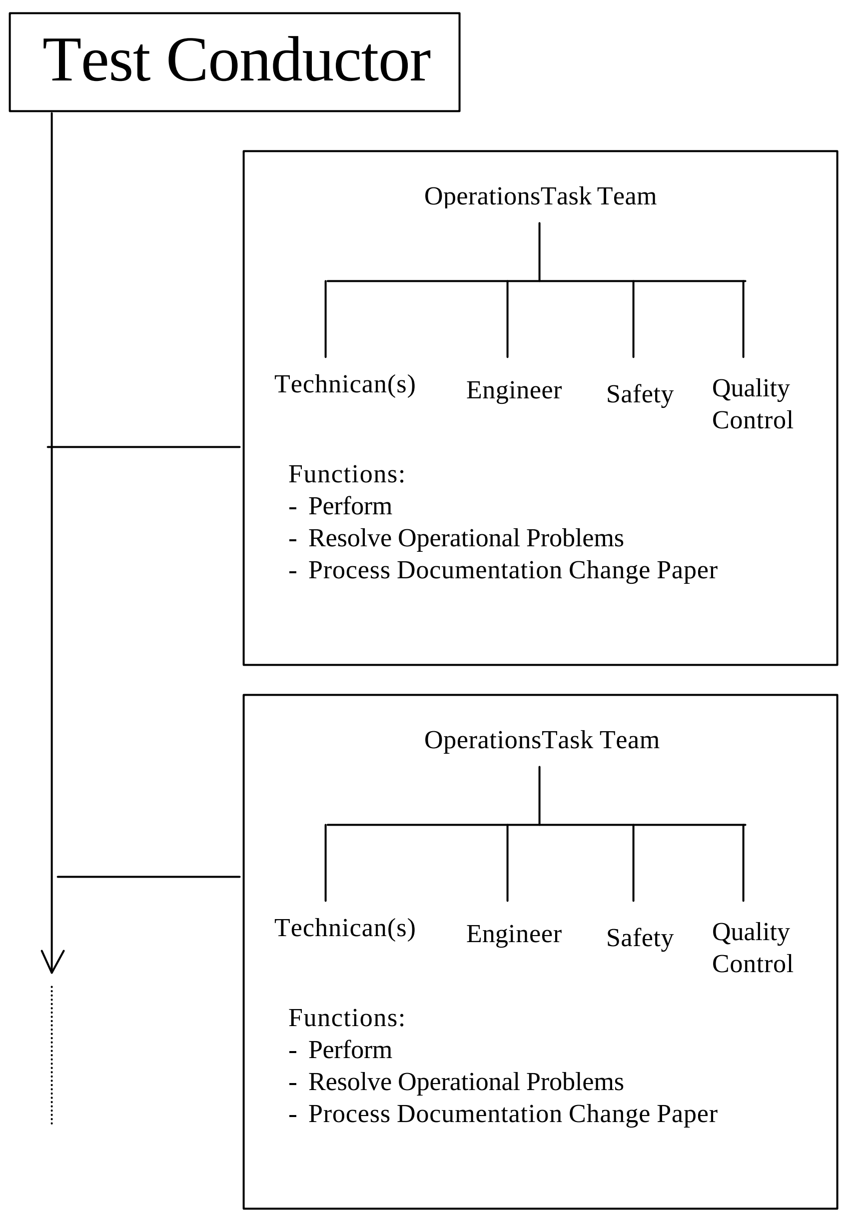


Figure 2.2-3 Test Conductor and OperationsTask Teams

Interviews with Test Conductors

During the on-site review Test Conductors and Team Leads were all asked, “what would you do if you had less the number of individuals explicitly identified in the OMI on hand to perform a critical task. “ In every case the individual responded that “borrowing and lending” critical skills between facilities (i.e., OPF, Vehicle Assembly Building (VAB), Launch Control Center (LCC), Hypergol Maintenance Facility (HMF)) is a common practice. It was explained that work-flow coordinators, referred to as “PAD Leaders” played a critical role in the negotiation of resources necessary to perform tasks properly. In every case, those interviewed emphatically indicated their willingness to call a halt (time-out) in any process step where, in their judgement, less than the required work force was present.

2.3 Work Review Processes

This section provides further information necessary to evaluate Hypothesis #1:

Reductions in the number of workers in Ground Operations will not affect the quality of work or safety of the vehicle because management processes exist, and are implemented, which assure work process fidelity, regardless of the labor pool size or composition.)

Work Review Processes include all requirements to evaluate and review work. The disposition of non-conforming work is also included in this area. Work Review Processes serve to validate that work is done properly and in a controlled manner, and have the potential to identify or flag problems that may be associated with process changes. This section discusses both USA and NASA work review processes shown in Figure 2.3-1.

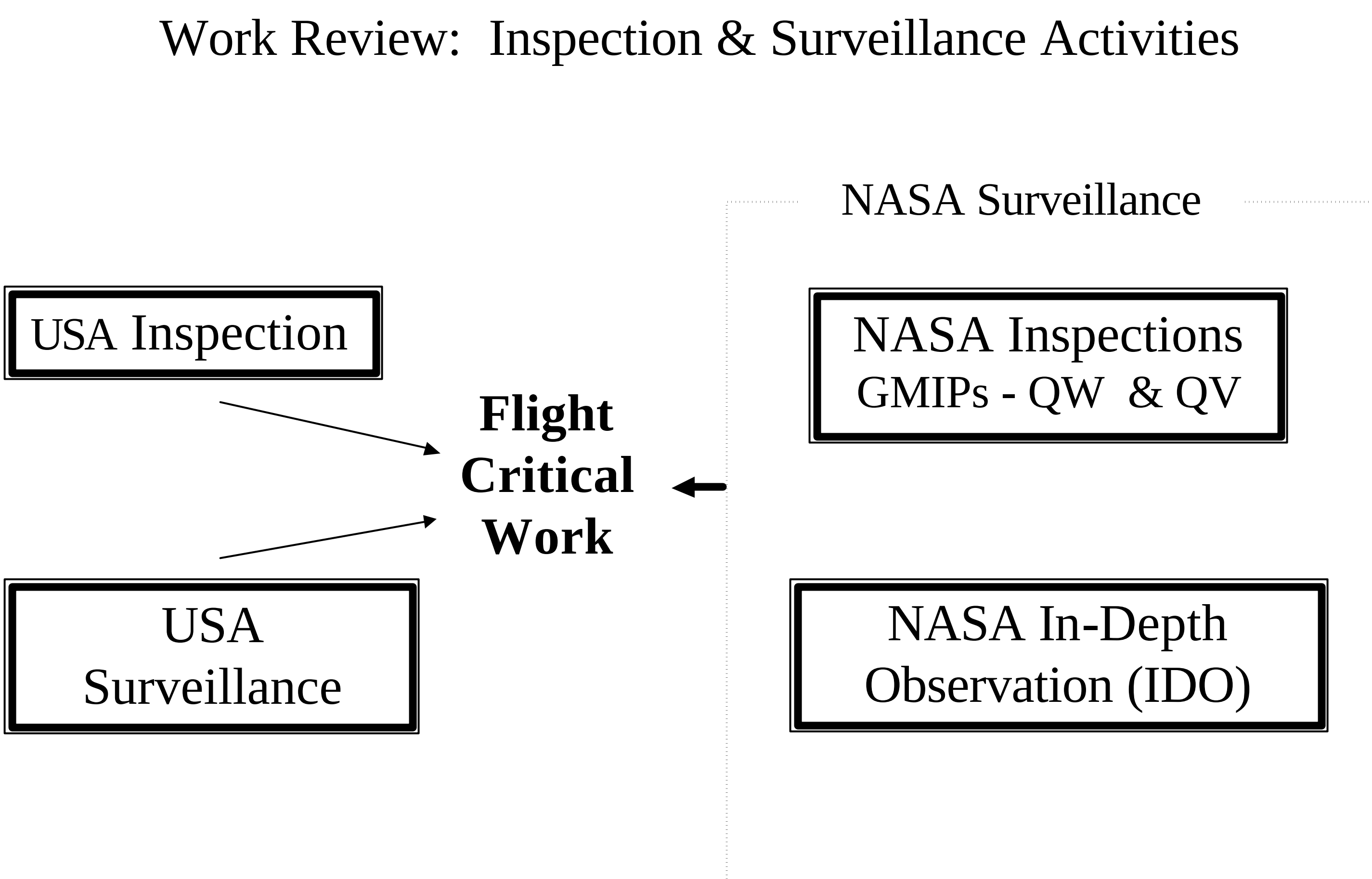


Figure 2.3-1 Work Review Processes

The Ground Operations review team conducted the following on-site activities related to Work Review processes.

- Evaluated (briefings and document review) USA inspection and surveillance processes
- Reviewed (briefings and document review) NASA inspection and surveillance activities
- Evaluated SPIs related to USA work review processes
- Discussed NASA "Critical Process" review initiative
- Reviewed USA Structured Surveillance Phase-2 initiative

Work Review SPIs

As discussed in Section 2.2.1, the GO review team, in concert with USA/GO and NASA/KSC/GO identified those SPIs most relevant to work control and work review activities. The list below identifies those SPIs that govern work review:

Vol II: Flight Hardware Processing

- QA-001(3) Problem Reporting and Corrective Action
- QA-017(3) Test and Inspection Record Station Operation
- QA-019(3) Material Review/Prime MRB Operations
- QA-049(3) Surveillance Inspection

The review team concluded that appropriate work review requirements were documented and are being implemented.

2.3.1 USA Work Review Processes

SFOC/USA Structured Surveillance Phase-2

In order to accomplish the same successful quality assurance program with fewer people USA has initiated a structured surveillance approach involving six highly-qualified and experienced inspectors who conduct daily surveillance of work and inspection activity using a "Design of Experiments" approach. This approach assures a statistically valid sampling of activities in various facilities. Surveillance is automated to a great extent, utilizing Palm Pilot hand-held computers, to identify the surveillance tasks and to record the observations.

Data is downloaded at the end of the day and running statistics and trends are available on the USA Intranet by the following morning. Surveillance activities are distributed with 40% in flight equipment, 40% in ground support equipment and 20% in general area surveillance. Inspections are randomly assigned within each category. This approach provides insight into the overall health of the quality inspection and task execution activities, across the full range of critical USA/GO processes.

USA Inspection

USA employs 223 individuals classified as quality inspectors in their current workforce. The NASA-approved Quality Planning Requirements Document (QPRD) defines "hard-coded" inspection requirements which are identified in each OMI. Inspections include "Tech" buys (inspections performed by technicians) and two types of Quality "buys," the quality verification (QV) and the quality witness (QW).

Product and Process Integrity Continuous Improvement (PPICI)

The PPICI program is designed to validate work process integrity and fidelity through a two-step process. The first step involves a tabletop review of the WAD or OMI: page by page, line by line. The second step involves going on the floor and verifying conformity of the actual work method to the written work instructions. This activity of "process proofing" is similar to the Marshall Space Flight Center (MSFC) based Product and Process Integrity Audit. The KSC PPICI is also being used as a method for improving work processes and instructions; e.g., use of more photographs and diagrams.

2.3.2 USA Management Review of Safety and Quality in Work Performance

Management Work Review Monitoring Forums

USA has established the Senior Management Quality Review Committee and the Senior Management Safety Review Committee to evaluate work force performance in areas of quality and safety. Meetings are held monthly with focus alternating each month between quality and safety. Any process performance issues that are determined to be either "yellow" or "red" require development of a corrective action plan with closed loop reporting due at the next meeting. Examples of safety and quality data reporting are provided in the following paragraphs, however analysis of the individual metrics is beyond the scope of this review.

Safety

USA reports safety metrics monthly for Facility and Maintenance Mishaps, Task Execution mishaps, OSHA reportable incidents, GSA vehicle accidents, and Incident / Error Review Board (IERB) incidents (see Figure 2.3-2). The monthly review also addresses NASA Safety Reporting System (NSRS) status, Hazard Report status, and provides a breakdown of first-aid injury causes. The following metrics are included in the safety bi-monthly process assessment:

First Time Safety
Facility Inspection Findings Closed
1S ESR's (top priority safety related Engineering Support Request (ESR))
2S ESR's (second priority safety related ESR)
Type A Mishaps
Type B Mishaps
Type C Mishaps
Mission Failures
Worktime Deviations
Incident Rate
GSA Vehicle Damage Rate
Lost Time Frequency Rate
Lost Time Severity Rate
OSHA/EPA Violations
OSHA Recordable Injury Rate
Property Damage

Quality

Quality reportable metrics include First Time Quality, OMI Deviations, Timeliness in Implementation of Corrective Action, WAD error rate, and 23 other measures of quality. Reporting also includes compliance with the ISO 9001 compliance status for each ISO element and the status of any necessary corrective actions. The following metrics are included in the quality bi-monthly process assessment:

Task Start Time Perfection
QPRD Planning
Pen & Ink Accuracy
OMI's with Excess Deviations Sample
Training Requirements Met
Parts Materials Provided Calibration – Tools Used
Task Rate Perfection
WAD Perfection at Closure
Workmanship PR's
QPR WAD Error Rate
WAD's Open at Launch
Two Way Memo Trend
Govt. Acceptance Rate
First Time Quality
On Time Audit Responsiveness
Corrective Action Timeliness
Corrective Action Acceptance
Overall ISO 9001 Standing (20 areas)
Inspection Deviations/Waivers
OMRS Waivers
Changes After LSFR

The GO review team recognizes the importance of metrics in monitoring the health of safety and quality critical processes. It was noted that USA/GO and NASA/KSC/Ground Operations are working together to develop a set of metrics (at the USA/GO core process level) mutually recognized as meaningful indicators of process health.

USA Safety (Quality) Focus in Work Performance: Monitoring Work Discipline Indicators at the Lowest Level

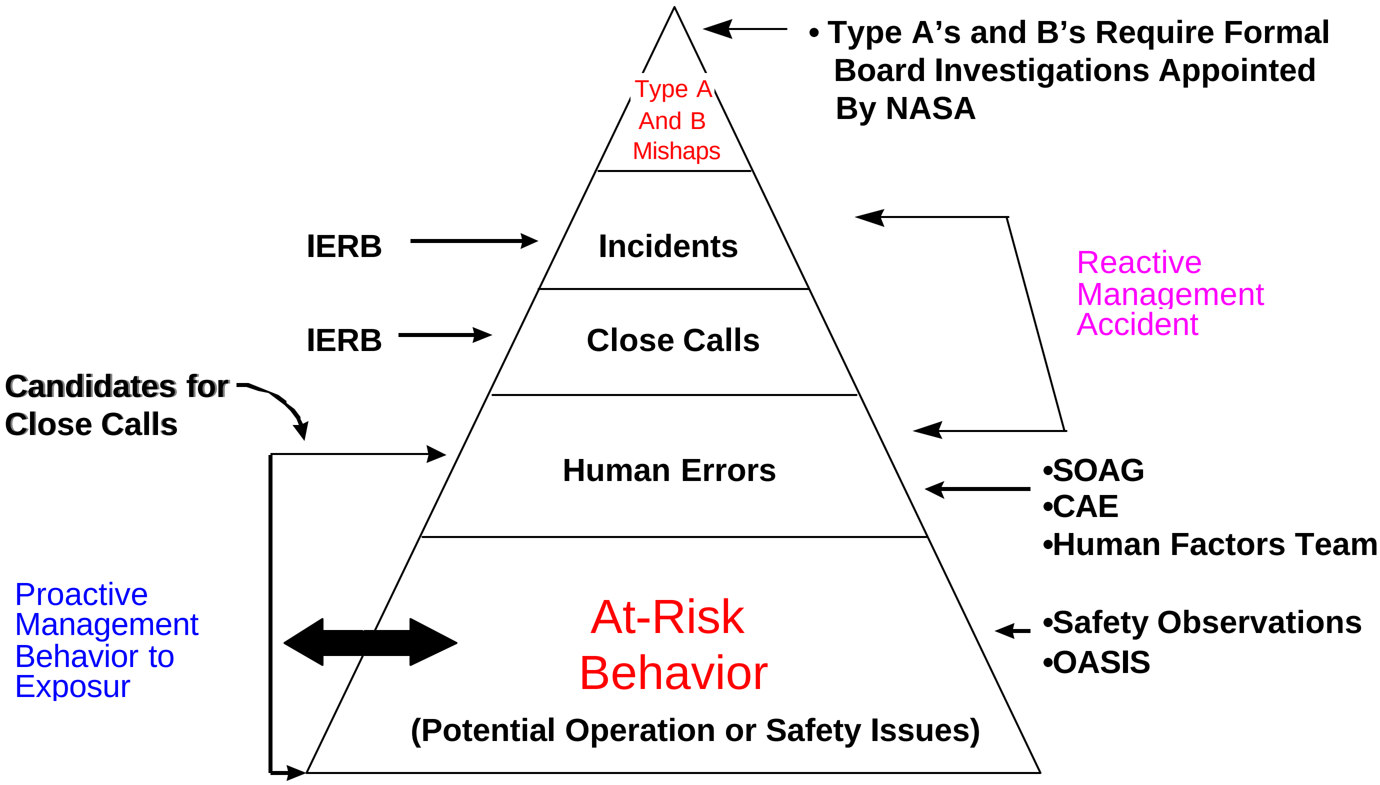


Figure 2.3-2 USA Ground Operations Event Reporting and Corrective Action Process Summary

Work Performance Monitoring and Metrics

USA Ground Operations uses four major systems to address processing escapes. These systems are the Incident/Error Review Board (IERB), Shuttle Operations Assessment Group (SOAG), Corrective Action Engineering (CAE), and Operational Area Safety Improvement System (OASIS).

Incident/Error Review Board (IERB)

The IERB is a Director-level management board that investigates processing events that meet the definition of a NASA Reportable Mishap as defined in NASA Policy Directive 8621.1G. The board develops a consensus regarding the appropriate corrective actions to be implemented in response to the event and tracks the corrective actions to closure. The corrective actions are also provided to the USA Ground Operations Mishap Coordinator for reporting into the NASA Mishap Reporting System.

Shuttle Operations Assessment Group (SOAG)

The SOAG is a Director-level management board composed of the same members of management that constitute the IERB. The SOAG investigates processing inefficiencies and less serious events that generally do not meet the definition of a NASA Reportable Mishap other than as a NASA Close Call Mishap.

Corrective Action Engineering (CAE)

The CAE process addresses processing quality issues resulting from direct notifications such as the Quality Discrepancy Notice (QDN). The CAE also reviews processing discrepancies from various sources like the Problem Reporting And Corrective Action (PRACA) data-base. The CAE investigates and validates inputs, analyzes the data for trends and causes, participates in implementation of identified actions, and tracks the actions to completion in the Quality Corrective Action Tracking System (QCATS) database.

Operational Area Safety Improvement System (OASIS)

The OASIS process uses work area teams that have been established to discharge area safety responsibilities. The teams proactively identify, analyze, recommend, and implement solutions to concerns brought forward by any member of the workforce. The teams provide inputs to the weekly “Safety Tailgate” meeting to educate the workforce on safety related work topics. They concentrate their effort on issues that can be worked efficiently at the area team level within a reasonably limited time frame. Issues identified but not worked by the OASIS teams are referred to Management or addressed by other processes like Continuous Improvement/Process Improvement for resolution.

2.3.3 NASA Work Review Processes

NASA KSC/SMA also plays an important role in work review of USA ground operations activity. A detailed assessment of the implementation of KSC/SMA roles and responsibilities is provided in Section 3.0 of this document. KSC/SMA performs two basic kinds of work review that are grouped under the term “surveillance”: 1) inspection, and 2) In-Depth Observation (IDO). Inspection and IDO both involve acquiring knowledge concerning the safety and quality of the activity. They can be defined by the following attributes:

Inspection

- an in-line activity
- part of the work process
- represents a process control (requires approval)
- is a constraint to proceed

In-Depth Observation

- an monitoring activity
- independent of the process
- intervention by exception
- is not a constraint to proceed

NASA Mandatory Inspection Points (MIPs)

In the context of this document, Government Mandatory Inspection Points (GMIPs) are points in a given process that require a government/NASA quality “buy-off”/approval before proceeding. There are 14,000 contractually required GMIPs in place at KSC that are “hard coded” or written into individual WADs (OMIs). GMIPs are performed by quality inspectors from the KSC Safety and Mission Assurance organization. Current planning calls for NASA MIPs (GMIPs) to be reduced from the current level to 5,000 - 6,000 by the end of calendar year 1998. USA quality mandatory inspection will continue, but without the mandatory government verification role. The reduction in GMIPs is being managed by the NASA/JSC Space Shuttle Vehicle Engineering Organization (SSVO) using a formal GMIP Reduction Review Plan.

NASA Critical Process IDO

In addition to USA inspection and surveillance, KSC/SMA and Process Engineering personnel have identified approximately 1300 critical process steps (each identified by a specific WAD or OMI) that NASA desires to observe. This form of surveillance, known as in-depth-observation (IDO), is not procedurally required and USA may proceed without the presence of the NASA observer. The criteria used to identify critical processes are included in Section 3.0 of this document.

Quality Planning Requirements Document (QPRD)

The QPRD defines what work activities are to be inspected and why. The QPRD is, in effect, a repository of lessons learned from the inception of the Space Shuttle Program. Accordingly, principal QPRD reference documents include the Failure Mode Effects Analysis and Critical Items List, the Fracture Control Plan, and Hazard Analysis Reports for each Space Shuttle element and critical facility and ground support system.

A QPRD is established for each on-site KSC contractor to identify inspection requirements for different types of work tasks. NASA Quality Engineering (QE) is responsible for the review and approval of the contractor-developed QPRD. NASA inspection requirements are identified in these QPRD’s. The NASA inspection requirements, identified as GMIPs, are complemented by KSC's Structured Surveillance Program.

These two approaches provide a balanced and flexible quality assurance program. The QPRD establishes ground rules for defining the quality requirements, specific responsibilities, and quality planning implementation methods for standard operations used in all work instructions.

Quality Verification (QV) and Quality Witnessing (QW) are the methods used to implement GMIPs. Some tasks can be verified later in the process and require only the technician's verification at the time the task is performed. Quality Inspection may be postponed until later in the task or process if verification can be made after completion and prior to close-out. Other processes or tasks may require that quality inspection witness (QW) the operation as it occurs. QW is used when:

- Evidence of accomplishment is lost by its performance or where the required attributes are unverifiable after work completion.
- An item must be compared against an established standard.
- The inspector is required to perform the task.

2.3.4 Conclusion: Work Control and Work Review Processes

<u>Working Hypothesis #1</u>

Reductions in the number of workers in Ground Operations will not affect the quality of work and safety of the vehicle because management processes exist and are implemented which assure work process fidelity, regardless of the labor pool size or composition.

Work Control and Work Review Processes discussed in Sections 2.2 and 2.3 of this report and evaluated during the on-site review, provide the basis to conclude that Hypothesis #1 is True.

2.4 Change Control Processes and Risk Management

Working Hypothesis #2

Changes in work processes (including implemented process improvements and initiatives) will not be allowed to compromise safety because management processes exist and are implemented which will assure continued work process fidelity.

The processes that govern change control include formal change boards and processes discussed in Section 2.4.1; risk management processes addressed in Section 2.4.2; management review processes examined in Section 2.4.3; and independent assessment processes outlined in Section 2.4.4.

The Ground Operations review team conducted the following review activities concerning change control and risk management:

- Evaluated (document review and briefings) Ground Operations Change Control Processes
- Reviewed WAD/TOP Change Control processes
- Reviewing SPI Change Control Processes
- Reviewed risk assessment and risk management mechanisms for all change control processes

2.4.1 Ground Operations Configuration Control Board

The following discussion outlines the structure and interactions of the Ground Operations Configuration Control Board (GO CCB) and the principal sub-boards that assist in managing change. The review team found that USA has implemented rigorous and thorough configuration management processes that will assure that process changes are carefully evaluated prior to implementation.

The GO CCB is the controlling authority for managing changes and requirements affecting the GO-assigned hardware/software (HW/SW), and for flight HW/SW and program requirements that require GO assessment and implementation, and for dispositioning changes that exceed the authority of its sub-board delegations. The GO CCB organization, authority, and areas of responsibility are depicted in Figure 2.4-1. The Board is chaired by the USA/GO Program Office and Integration (PO&I) Director or designee. Program Coordination provides administrative support and is responsible for the change control and meeting support activities for the Board, including processing, managing, and status accounting of changes. Meetings are held as required by the Chair. Changes and requirements requiring GO CCB review and concurrence/disposition are handled through the appropriate ground operation change process as described in the following sections.

USA/GO CCB Authority and Relationships

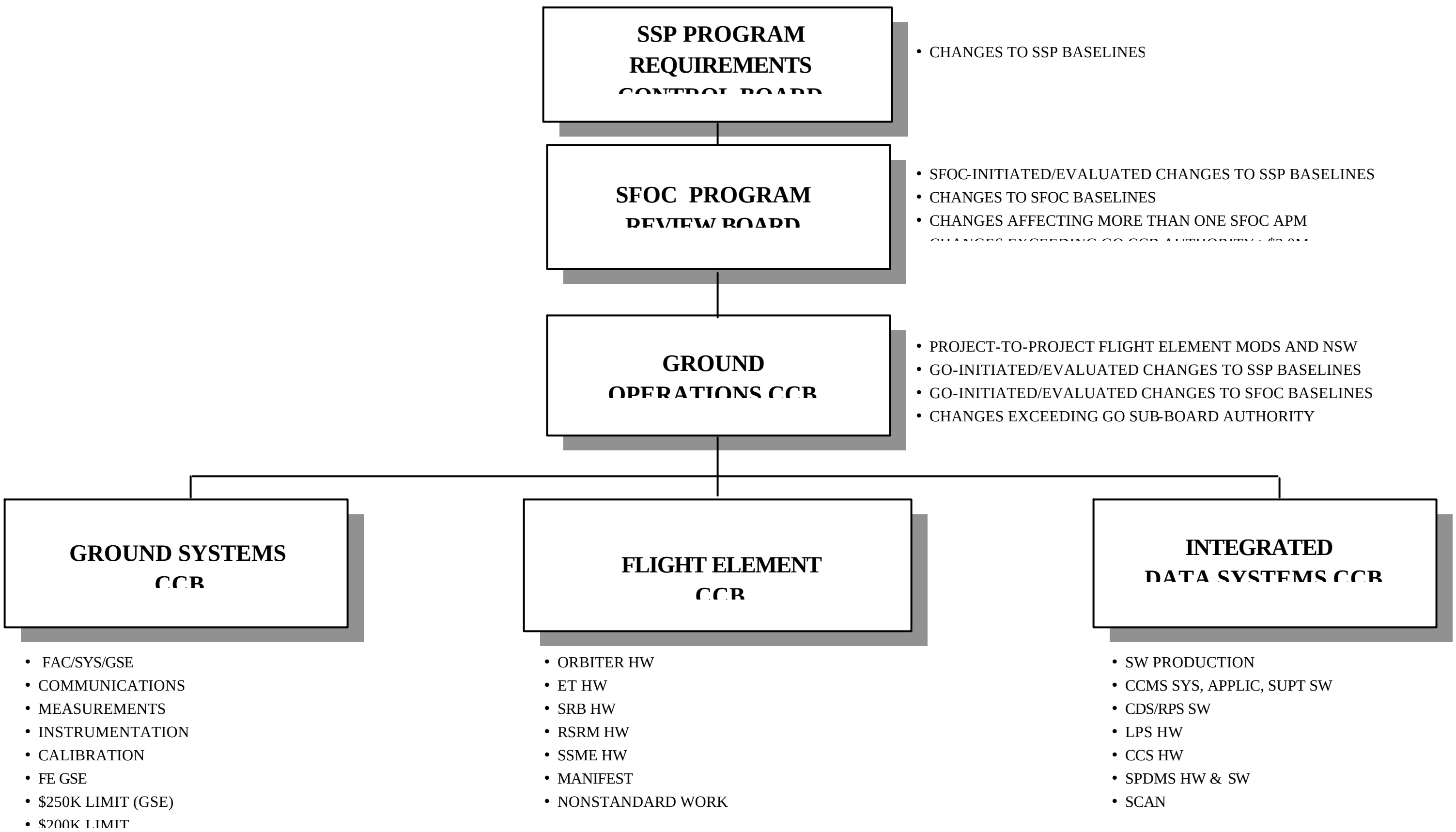


Figure 2.4-1 USA/GO Configuration Control Board

The GO CCB is supported by the overall ground operations organization and subcontractor(s). The GO CCB membership is as follows:

- Chair - Director, Program Office and Integration
- Secretary - Program Coordination
- Members
    - Integrated Data Systems Director
    - Shuttle Engineering Director
    - Horizontal Processing Director
    - Vertical Processing Director
    - Ground Systems Support Director
    - Safety and Mission Assurance Director
    - Chief Engineer

There are subtle but significant differences regarding GO requirements and responsibilities for "Ground Hardware/Software" and "Program/Project Requirements." These are described more fully in the following sections. In general, for Ground Hardware/Software items, USA/GO has disposition authority for changes based on dollar threshold, and is responsible for all aspects of the configuration identification, control, and verification. For Program/Project items, USA/GO has limited disposition authority for flight hardware changes and is basically only responsible for the assessment and implementation/verification aspects of the process. The GO change control process includes the sub-functions of initiation and submission, screening, assessment, and impact identification, disposition, implementation, verification, and close-out. This process is illustrated in Figure 2.4-2.

Change and Verification Managment Process

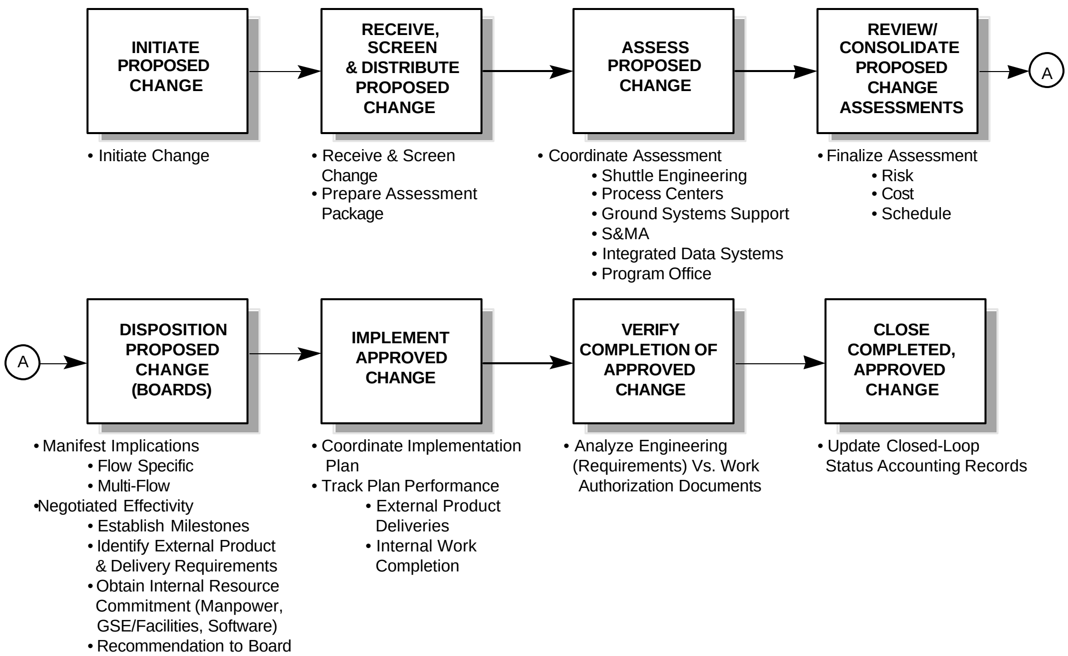


Figure 2.4-2 Change and Verification Management

<u>Ground Hardware/Software</u>

Changes affecting HW/SW under GO sustaining engineering and/or O&M responsibility are processed by the appropriate GO change control organization as described in the following paragraphs.

Ground Systems CCB Sub-Board

The GO Ground Systems (GS) CCB is the delegated authority to manage and disposition changes affecting ground HW configuration baselines, within specified limits. Resources and Program Management (R&PM) is responsible for the change control activities of the GO GS CCB, including processing, managing, and status accounting of ground HW changes. The R&PM Manager, or designee, chairs the Sub-Board and makes the final commitments for GO to proceed with implementation. GO engineering, operations, and support organizations provide representatives and technical support to the Sub-Board.

Integrated Data Systems CCB Sub-Board

The GO Integrated Data Systems (IDS) CCB is the delegated authority to manage and disposition changes to the Launch Processing System (LPS) and the Integrated Processing System (IPS) HW/SW configuration baselines. Data Systems Integration and Support Services is responsible for the change control activities of the GO IDS CCB, including processing, managing, and status accounting of changes to LPS and IPS HW/SW. The IDS Director or designee co-chairs the Sub-Board with the NASA KSC Process Engineering (PK) Directorate to make the final commitments for GO to proceed with implementation. GO engineering, operations, and support organizations provide representatives and technical support to the Sub-Board.

The GO GS and IDS CCBs also support the SFOC Program Review Board (PRB) and NASA SSP Program Requirements Control Board (PRCB) by providing impact assessments and recommendations on all changes within their areas of responsibility as detailed above.

Program/Project Requirements

Changes affecting flight HW/SW and other program requirements that require GO assessment and implementation are processed by the appropriate GO change control organization. The GO Associate Program Manager (APM) or designee (GO CCB) and the NASA and USA element program/project managers are delegated limited change control authority, from the SSP, to approve flight HW changes and nonstandard work (NSW) requirements to be implemented by SFOC. GO Program Coordination provides change control support to the GO APM for flight HW and NSW requirements processed project-to-project via the Shuttle Project Action Request (SPAR) process, including processing, managing, and status accounting.

Flight Element CCB Sub-Board

The GO Flight Element (FE) CCB is the delegated authority to manage and authorize GO implementation of changes affecting flight HW. Flight Requirements Planning and Control (FRP&C) is responsible for the change control activities of the GO Flight Element CCB, including processing, managing, and status accounting of flight HW changes and NSW requirements. The FRP&C Manager, or designee, chairs the Sub-Board and provides recommendations and the GO position on proposed changes, and makes the final commitments for GO to proceed with the implementation of NASA approved changes. GO engineering, operations, and support organizations provide representatives and technical support to the Sub-Board.

Three Critical Change Control Cases

The following three cases are provided as objective evidence of change control in safety and quality-critical activities: development and change of SPIs, TOP/WAD development and change, and GMIP change.

SPI Change Control Process

The Standard Practice Instruction (SPI) Change Control Process is governed by USA/GO Document Number BM-001(1)K. USA personnel briefed the review team on the mechanics of the SPI Process. The purpose and scope of the Standard Practice Instruction (SPI) Change Control Process is to define the system for initiation, revision, publication, and management control of SPI's. The Space Flight Operations Contractor uses SPI's to ensure consistent application of policies and procedures and to define NASA and other contractor interfaces required to manage identified tasks. SPI development and revision flows are show in Appendix A. All personnel are instructed to obtain and verify the latest signed copy from the official web site. The Original is signed." All critical SPIs require NASA reviews and approval before publication.

TOP/WAD Change Control Process

All proposed changes and revisions to existing work authorization documents (e.g. OMIs) are required to undergo a rigorous review and approval process which includes the authorization signature loop employed in development of the original document. Individual OMI's include "Work Instruction Change Request" records and revision records immediately under the cover page. Each change request sheet incorporates detailed information concerning the change, along with concurrence signatures and dates from affected organizations, including Process Planning and the Instruction Change Request Change Control Board (ICR CCBD).

Instructions for the processing of changes are contained in the following Standard Practice Instructions:

- QA-001(3) - Problem Reporting and Corrective Action (PRACA)
- SP-504(2) - Test Preparation Sheet (TPS) Processing
- SP-511(2) - Deviation Processing
- SP-514(2) - OMI Preparation and Release
- SP-519(2) - OMI and OM Implementation

The change level can influence the approval level. For example, a pen-an-ink change that corrects spelling may be performed with lower approval than a change that revises a test specification. In the course of performing large, complex operations, such as a launch countdown, the approvals for accomplishing even a minor change can get quite extensive. The approval matrices contained in these (and other SPIs) reflect these conditions.

GMIP Change Control Process

The government mandatory inspection points (GMIPs) are written into work procedures by the USA employee in accordance to a KSC Quality Procedure Requirements Document (QPRD). A change to an inspection point in a work procedure must be authorized by the author (USA employee) and a NASA counterpart at a minimum and must be in accordance with the QPRD. The NASA GMIP change management process involves coordination with the cognizant design-centers (MSFC or JSC), safety and mission assurance organization and notification of the Human Space Flight Assurance Board.

A change to the QPRD, from a GMIP standpoint, can only be accomplished by the USA Manager of Quality Engineering with an approval letter from NASA Quality Engineering requesting the change. The QPRD is an online document that is available to all procedural authors. NASA KSC currently develops the criteria for what operations or tasks will require GMIPs. These criteria have been related to USA via GMIP requirement letters.

2.4.2 USA Risk Management Requirements

The USA corporate risk management philosophy has been deployed throughout the SFOC/USA Ground Operations activities at KSC. Both the SFOC contract and USA policies require that formal risk assessments for proposed changes be brought before various program control boards.

Space Shuttle Program Boards

Principal Space Shuttle Program change control forums are identified in the following list:

- Program Requirements Control Board (PRCB)
- Daily PRCB
- Space Shuttle Upgrades (SSU PRCB)
- Integration Control Board (ICB)
- Flight Progress Support Working Group (FPSWG)
- Daily Mission Integration Control Board (DMICB)
- Flight Specific Integrated Process Teams (IPTs)
- Vehicle Engineering Control Boards (VECB)
- Shuttle Avionics System Control Board (SASCB)
- Payloads Operations Center Configuration Control Board (POC CCB)
- Flight Crew Equipment Configuration Control Board
- Remote Manipulator System CCB
- Orbiter Review Board (ORB)
- Launch & Landing/Integrated Data Systems Configuration Control Board

The Evaluation Process

It is USA policy to apply formal risk management procedures to all Space Shuttle Program Change Requests that have a potential to increase risk to safety, schedule, cost, mission success, or supportability.

Ground Operations Initiated Changes

The initiator of any proposed change from within the Ground Operations community is the "owner". The owner makes the first determination as to whether the change represent increased risk (safety, mission success, cost, schedule, supportability) to program goals?

- If "YES" - initiator applies scorecard; fills out SFOC Change Evaluation,
- If "NO" - a risk assessment is not required
- If "Undecided" - initiator seeks assistance
- Instructions are contained in SPI BM-311(2)K

Externally Initiated Change Request

The Ground Operations Risk Coordinator makes the first formal assessment, (risk "triage") to determine if a proposed change represents a safety or program risk. The coordinator is a senior engineer who evaluates and sorts changes based on the potential criticality of the proposed change. If the risk is determined to be significant then all applicable documentation is distributed to a special USA/GO "Change Evaluation Team". The formal risk assessment is conducted and the Ground Operations Risk Coordinator presents the assessment to management. All changes follow the standard signature processing route. The standard risk assessment form is shown in Figure 2.4-3.

SFOC Risk Assessment Form (DRD 1.1.1.4-b)		
Change #	**Evaluator / Initiator Name & Org:**	**Date:**
Title of Change:		
Are there any changes to baselined safety risk documentation (e.g. Hazard Reports/CILs) associated with making this change? ☐ Yes ☐ No **If yes, identify impacts:**		

Complete Part I or Part II of this section:
PART I
☐ **This change results in no significant increase in risk (green*).** This evaluation is based upon: ☐ Experience/Consultation ☐ Analysis
PART II
☐ **This change results in significant increase in risk (yellow** or **red*).** Risks and associated risk cause(s) are as follows: Risks listed above would impact the following (address only those that apply): ☐ Safety ☐ Mission Success ☐ Supportability ☐ Schedule ☐ Cost The consequence and likelihood (high, moderate, unlikely, remote or improbable) of each impact follows: Risk mitigation options and recommendations follow: * Assessment determined utilizing the SFOC Risk Assessment Scorecard

Figure 2.4-3 Risk Assessment Form

The USA risk management assessment process involves assigning a risk score, based on severity of consequence, broken down into the five elements: safety, mission success, schedule, supportability, and cost (Table 2.4-1), and likelihood of occurrence (Table 2.4-2). The resulting risk scores are entered into a multiplication matrix (Figure 2.4-4) where risk values are determined for the five areas of concern. The review team found that USA's risk assessment process is implemented and that risk management training is being offered at all levels of the USA/GO organization.

TABLE 2.4-1 RISK CONSEQUENCE DESCRIPTIONS

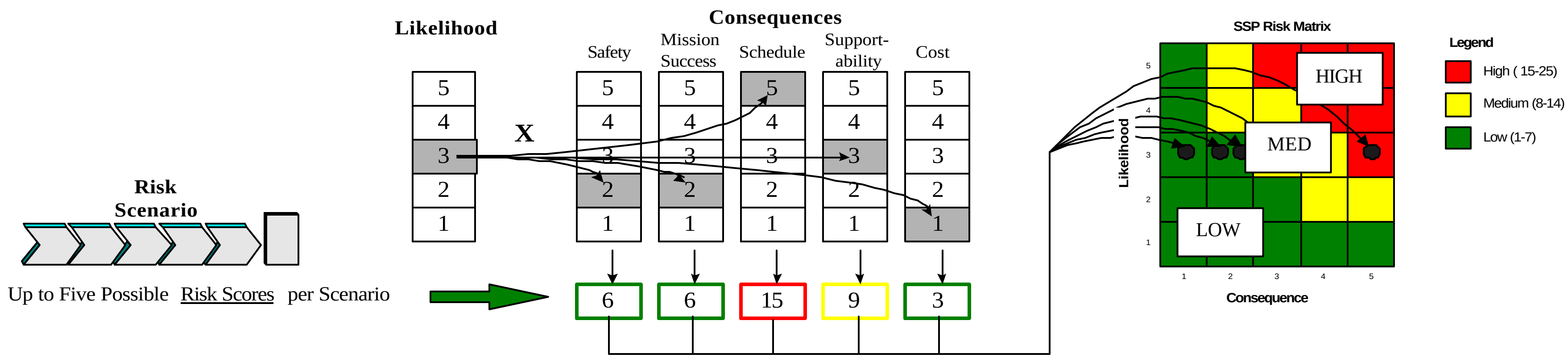
Score	Safety	Mission Success	Schedule	Supportability	Cost
5	Death **Loss of** 1) Major Essential Flight Element, or 2) Critical Ground System Violation of federal or state regulations 1) OSHA: Willful, Serious, or Repeat Violation, or 2) EPA: Major Violation	Pad Abort / Intact Abort Early mission termination resulting in ACLS / ELS landing * Failure to provide adequate training to crew; or sufficient certified ground controllers, analysts, or planners for safe flight and ground operations	> 2 flight decrease in annual flight rate	Loss of all maintenance capability (expertise, spares, vendors) for 1) Major or Non-Major Essential Flight Element, or 2) Critical or Process Sensitive Ground System Major increase in maintenance time or major decrease in reliability for 1) Major or Non-Major Essential Flight Element, or 2) Critical or Process Sensitive Ground System	> $25 M
4	Permanent Disability * **Loss of** 1) Non-Major Essential Flight Element, or 2) Process Sensitive Ground System	Failure to meet all Major Mission Objectives (MMO)	1 - 2 flight decrease in annual flight rate >= 1 day Flight Delay occurring after L-2	Serious reduction in maintenance capability (expertise, spares, vendors) for 1) Major or Non-Major Essential Flight Element, or 2) Critical or Process Sensitive Ground System	$ 5 M- $ 25 M
3	Serious Injury / Illness * **Significant damage** to 1) Major Essential Flight Element, or 2) Critical Ground System **Loss of** 1) Non-Essential Flight Element, or 2) Non-Critical Ground System Violation of federal or state regulations 1) OSHA: Violation (other than serious), or 2) EPA: Moderate Violation	Failure to meet one MMO * Failure to meet trajectory or resource requirements for completion of 1 MMO * Failure to provide adequate training to crew; or sufficient certified ground controllers, analysts, planners for completion of 1 MMO *	>= 7 day delay of L-2 MMT from Delta LSFR Baselined Launch Date	Loss of all maintenance capability (expertise, spares, services, vendors) for 1) Non-Essential Flight Element, or 2) Non-Critical Ground System Major increase in maintenance time or major decrease in reliability for 1) Non-Essential Flight Element, or 2) Non-Critical Ground System	$ 1 M - $ 5 M
2	**Significant damage** to 1) Non-Major Essential Flight Element, or 2) Process Sensitive Ground System	Early mission termination resulting in PLS landing * Flight readiness problem for SSV, Ground / Flight Systems resulting in LCC violation *	< 7 day delay of L-2 MMT from Delta LSFR Baselined Launch Date	Serious reduction in maintenance capability (expertise, spares, vendors) for 1) Non-Essential Flight Element, or 2) Non-Critical Ground System Minor increase in maintenance time or minor decrease in reliability for 1) Major or Non-Major Essential Flight Element, or 2) Critical or Process Sensitive Ground System	$100 K - $ 1M
	Minor Injury / Illness * **Significant damage** to	Flight readiness problem for SSV,	Adds 1 or more	Minor increase in maintenance time	

1	1) Non Essential Flight Elements, or 2) Non-Critical Ground System Violation of federal or state regulations 1) OSHA: De Minimis Violation, or 2) EPA: Minor Violation	Ground / Flight Systems resulting in need for multiple waivers for certification of flight readiness (COFR) *	new launch constraints	or minor decrease in reliability for 1) Non-Essential Flight Element, or 2) Non-Critical Ground System	< $ 100 K

Table 2.4-2 Risk Likelihood Descriptions

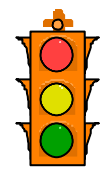
Score	Probability of Occurrence
5	**HIGH** ($Pr \geq 0.1$) • May be expected to occur once in one year of operation, or 6-10 flows • May be expected to occur more than once in program lifetime
4	**MODERATE** ($0.01 \leq Pr < 0.1$) • May be expected to occur once in 5 years operation, or 30 - 50 flows • May be expected to occur once, and could occur more than once in program lifetime
3	**UNLIKELY** ($0.001 \leq Pr < 0.01$) • May be expected to occur once in 10 years operation, or 60 - 100 flows • Could occur once in program lifetime, but multiple occurrences extremely unlikely
2	**REMOTE** ($0.000001 \leq Pr < 0.001$) • May be expected to occur once in 100 years operation, or 600 - 1000 flows • Occurrence during program lifetime extremely unlikely • Normally outside the operational envelope, limited hardware and operational safeguards exist to prevent completion to failure
1	**IMPROBABLE** ($Pr < 0.000001$) • Occurrence theoretically possible but such an occurrence is far outside the operational envelope and robust hardware and operational safeguards exist to prevent completion to failure

Figure 2.4-4   Risk Scoring Process



Risk Scenario Scoring Example

Identify and Assess Risk



High	REQUIRED
Medium	RECOMMENDED
Low	NOT REQUIRED

1. Identify the Risk Scenario by answering: *What can go wrong?*
2. Gather information about the scenario. Include facts, circumstances, and events that can cause the scenario to occur.
3. *How likely is it?* Assess Risk Likelihood by locating the most accurate likelihood description on the score card (one scenario likelihood score).
4. *What are the consequences?* Assess Risk Consequences by locating the most accurate descriptions among all categories on the consequence scales (up to five consequence scores).
5. Compute the Risk Scores: multiply the consequence scores (one from each category) times the scenario likelihood score to derive up to five risk scores

6. Plot the scores, choose the highest, and follow Action /Notification requirement based on "stoplight" scale

2.4.3 Management Review Forums

The NASA Space Shuttle program and USA employ extensive management review processes that afford additional opportunities for middle and senior management to control and monitor program changes as well as other program issues.

Principal reviews are highlighted as ovals in Figure 2.4-5, which depicts, at a high level, the integration and flow of ground processing activities. Ovals within boxes represent NASA responsibilities.

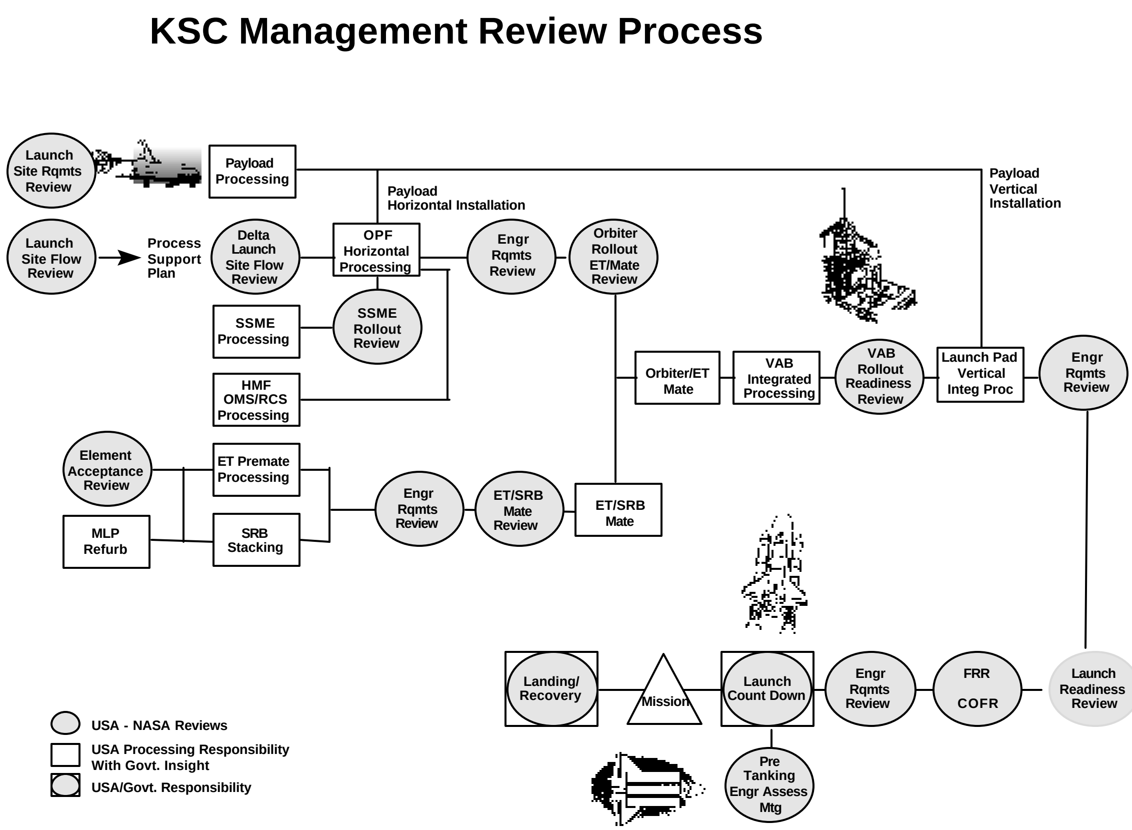


Figure 2.4-5 KSC Management Review Process

The management review process follows the traditional aerospace practice of resolving issues when possible at lower level boards in which controversial issues or issues still in-work (not yet resolved) are elevated to higher level boards. All open issues are resolved or are formally "dispositioned" (addressed with a documented decision) prior to launch.

The review team found that USA/GO employs rigorous and thorough management review at critical milestones within the Space Shuttle processing flow. These review activities and the recurrent involvement of senior management in USA/GO activities serves to further assure that process changes will be carefully reviewed.

2.4.4 Internal and Independent Assessment

Complex risk management issues invariably benefit from an informed and knowledgeable second opinion. This function provides senior management with a perspective, evaluation, analysis, or opinion independent of the line management hierarchy. Independent Risk Management Review is applicable to planning, design, test data, technical, and decision reviews as well as any other forum in which risks are identified, traded, mitigated, or accepted. The majority of audits are performed to provide proof that operations are conducted in conformance with established procedures. The following independent review activities provide insight for USA Ground Operations program managers.

- **Self-Audits** are performed, informally, by all of Ground Operations Management, for quality, safety, and any other areas determined to be important to success. The results of self-audits are worked by the management team.

- **Internal Audits** are performed by USA Operations Assessment on a risk-based (status/importance) audit schedule. These audits are focused on the Quality Program but also examine safety and areas of contractual compliance. The detailed results of these audits are forwarded to the responsible management for corrective action. Audit reports are distributed to GO Management, USA Management, and the NASA audit staff for oversight. Audit metrics are summarized and reviewed bi-monthly at Ground Ops Management Reviews.

- **USA Corporate Internal Audit** prepares an annual risk-based audit plan of USA operations. The annual audit plan is reviewed and approved by the USA Management Audit Committee. The USA Internal Audit is currently evaluating Year 2000 readiness across the company. USA Internal Audit also performed an independent assessment of the Ground Operations Quality Audit Staff's (Operations Assessment) review and monitoring of ISO 9001 during 1998.

- **NASA audits** are performed by a number of branches within NASA. Quality and safety audits are scheduled, and random audits are also conducted. The most recent audits under SFOC were: “Process/Fabrication Controls” conducted December 1997 and 'Open WADs at Launch' conducted 2nd quarter of FY 1997. The audit data were recently re-validated in preparation for the final report. NASA provides the reports to GO management for corrective action.

- **ISO 9001 Audits** are performed by the registrar, Det Norske Veritas. USA GO attained their ISO 9001 certification on October 17, 1997. Registration Maintenance audits are planned on a 6-month cycle. USA has undergone compliance verification audits (April 13, 1998, and September 28, 1998) and is scheduled for another follow-on audit on April 5, 1999.

- **USA's Environmental Safety and Health Department** conducts regular internal inspections/audits and facility walkdowns to assure compliance with the defined Environmental Safety and Health Program. Findings are reported to local management for correction and data are accumulated and briefed to senior management on a regular basis.

- **OHSA** retains the prerogative to audit Safety Programs in USA for effective compliance with Federal Occupational Safety and Health Laws. There have been no OSHA audits of USA, but there have been periodic inquiries and fact finding visits by regional OSHA inspectors in response to employee complaints. These issues, when surfaced, are reported to both local NASA management and USA management; USA management is responsible for implementing any corrective action required.

- **Environmental Regulatory Agencies** also inspect/audit USA on a regular basis to ensure compliance with the USA Environmental Program and for compliance with Federal and Local Laws. Findings are reported to both local NASA management and USA management; USA management is responsible for implementing corrective action.

- **Government audits (performed by Government Accounting Office, Office of the Inspector General, etc.)** are performed when deemed necessary by those agencies. There has not been a determined need for such audits in Ground Operations in the past 2 years.

- **Quality Audits** (performed by all agencies plus consultants engaged by those agencies) augment the other NASA audits of Ground Operations. There has not been a determined need for those audits in the past 2 years.

- **The Aerospace Safety Advisory Panel (ASAP)** reviews and evaluates current and future NASA programs and activities and reports its findings to the NASA Administrator. Priority is given to programs that involve the safety of human flight. ASAP most recently reviewed USA ground operations activity on August 19, 1998.

2.4.5 Change Control Requirements Documents

The review team confirmed that USA/GO change control processes are formally documented in policies and procedures including the following:

- Vol II - BM303(2) Flight Element Configuration Accounting
  BM-315(2) Launch Site Requirements and Flow Reviews

- BM-317(2) Ground Systems Configuration Accounting

- BM-323(2) Flight Element Change Control

- BM-326(2) Ground Systems Configuration Control Board Operations

- BM-332(2) Integrated Data Systems Configuration Control Board

Risk Management Requirement Documents

- KSC-5000-4501, "Ground Operations Risk Management Implementation Plan"

2.4.6 Conclusion: Change Control and Risk Management Processes

Working Hypothesis #2 Changes in work processes (including implemented and planned initiatives) will not be allowed to compromise safety because management processes exist and are implemented which will assure continued work process fidelity.

Change Control and Risk Management Processes discussed in Sections 2.4 of this report and evaluated during the on-site review provide the basis to conclude that Hypothesis #2 is True.

2.5 USA Process Improvement and Efficiency Initiatives

Working Hypothesis #3

Process improvements and efficiencies will be implemented in a fashion that will support increased manifest demands expected in mid - late CY 1999.

Opportunities Exist to Blend Technology with Process Control

The review team noted that technicians and first line managers indicated that 40 to 70 percent of their time associated with doing a work-task is associated with "paper," i.e. the administrative documentation and management tasks necessary, and intrinsic, in working on flight/safety critical aerospace hardware. The review team believes that real opportunities exist to achieve efficiencies by infusing state-of the-art information and communications technology into existing paperwork processes (e.g., WAVE). The key point to note is that the process fidelity is not changed, only the supporting administrative infrastructure is altered. Many of the proposed USA/GO initiatives are oriented toward streamlining paper processes.

Process Change Safety Risks are Controlled – Flight Safety Should Not be Compromised

Hypothesis #3 involves *Mission Success* issues. The review team found that work-task execution fidelity and flight safety is protected by excellent work control, work review, and change control processes. As long as process changes are developed and implemented within the current management framework, safety should not be compromised.

Saturated Ground Operations Capability

At some point in the future, the International Space Station launch and build demand will drive the KSC Ground Operations organization to a point of saturation. If the work control, work review, and change control processes are as good as we believe they are, the processes will not allow safety to be compromised. Nonetheless, a saturated USA/GO organization should be monitored carefully, with particular attention devoted to human factors. The work flow capability of Ground Operations, and to some degree the availability of critical flight components and facilities, will determine the maximum safe launch rate. The manifest will necessarily adjust to these limitations.

The Need for Ground Operations Baseline Definition

The review team noted that a workforce baseline, the minimum number of individuals to perform flows, is difficult to identify at the task execution level (OMI). While the minimum number is implicit in most of the process documentation reviewed, the Task Leader judgment and experience is the ultimate work control mechanism. The lack of precision in defining the minimum workforce makes capability forecasting difficult. USA process baselining activities may resolve this concern by explicitly defining the time and labor force required to perform tasks at the bottom level of the task definition structure. Another benefit of defining minimum resource loading is reduced dependency on human factors, such as Task Team Leader judgement, which may or may not always be as experienced and skilled as the present workforce.

2.5.1 A Look at the Improvement and Efficiency Initiatives

Table 2.5-1 provides a summary of process improvement and efficiency initiatives projected by USA/GO to provide work avoidance savings greater than one million dollars. The unit in the far right-hand column is Full Time Equivalent (FTE) employees. The projected savings for each project has been estimated by USA by interviewing workers and acquiring estimates of hours saved per task. These estimates are summed into

FTE estimates. A brief description of the most promising initiatives, grouped by projected FTE yield, is described below.

Table 2.5 –1 Improvement and Efficiency Initiatives

Legend
P: Processing or Touch Labor
S: Off-line or administrative support

Initiative Title	Int-Ops Prgm Off		H&V Shops Labs		Info Int Data Sys		Surv Insp. SMA		WAD Gen Eng		GSE Facil/Equip Maint Support Ops		Total Equiv FTE
	P	S	P	S	P	S	P	S	P	S	P	S	
Develop skills-based workforce			21	7			4	1	5	3			41
Fair wear & tear specifications			4	3			2	1	5	3			18
Internet provided maintenance & repair manuals			4	4			1	1	4	3			17
Centralize LAN administration		1				4				2		3	10
Eliminate Safety WAD approvals							2						2
Structured Surveillance Phase II							9	6					15
Transition of Safety toxic vapor checks to Proc Ops							6	2					8
Transition of Safety clear verification to Proc Ops							8	2					10
ET-SRB/Vertical Enhancement Teams			10										10
GOFOIT Team					9	9							18
Automated KICS schedule				2									2
Develop & Initiate Processing Center concept			49				7		4				60
Deviation reduction			2	1			1	1	5	2			12
Fork lift leasing program												3	3
Combine EDAMS & initiate CMMS system				29								12	41
WAD Authoring & Validate Environment (WAVE)					4	1			5	3			13
PeopleSoft Implementation					3	2							5
Reduce number of calibrations being performed								2				15	17
Eliminate/minimize chits, etc after LSFR									1				1
Provide desk-top CBT training capability				3		2		2		1		2	10
Total		1	90	49	16	18	40	18	29	17		35	313

Group 1: Highest Projected Savings

- Develop and Implement Processing Center Concept (estimated 60 FTE saved)

The purpose of this initiative is to implement a management structure that supports key areas of Shuttle processing, manages key processes through common objectives and metrics, drives decision-making to the lowest possible work level, aligns support from other organizations with key processes, and centralizes process accountability.

- Develop Skills-Based Workforce (estimated 41 FTE saved)

This initiative represents a new certification/qualification program. The purpose of this program is to develop an optimal method of efficiently providing trained, qualified, and certified Shuttle processing technicians and inspectors. The skill-based workforce is based on the concept that if the workforce has multiple skills, they will be used more to perform multiple tasks. Currently, the workforce is trained and qualified to work with individual systems or components. The objective is to broaden their capability to perform multiple tasks.

- Combine Engineering Data Access Management Systems (EDAMS) and Computerized Maintenance Management System (CMMS) (estimated 41 FTE saved)

Automate an existing manual system to schedule parts, paper, and people involved with facility operations and maintenance.

Group 2: High Projected Savings

- Fair Wear and Tear Specification (estimated 18 FTE saved)

This initiative calls for development of a specification that permits minor defects such as "cosmetic appearance" to be repaired by minimal paper, or "fly as is," until time/resources permit repair. (Current drawing requirements mandate a "new" condition.) This will be accomplished by documenting expected wear from nominal use so that the technicians will be able to disposition expected conditions without non-value-added paperwork.

- Ground Operations / Flight Operations Integration Team (GOFOIT) (estimated 18 FTE saved)

This initiative provides an integrated approach to combining seven related improvement activities.

1) Phase out analog (magnetic) tape data acquisition systems and replace with digital systems
2) Establish common "HELP DESK" tools and automation systems
3) Establish common tools for use in Kennedy Avionics Test Set (KATS) and Shuttle Avionics Integration Laboratory (SAIL)
4) Standardize JSC/KSC networks and data transmission systems
5) Consolidate software licenses
6) Consolidate maintenance agreements
7) Consolidate networks, help desks, and 24 hr monitoring functions

- Internet provided maintenance and repair manuals (estimated 17 FTE saved)

This initiative would implement a library of instructions, available to the work floor via the USA/GO Intranet for the performance of routine maintenance and repair to reduce engineering workforce involvement.

- Reduce Number of Calibrations Being Performed (estimated 17 FTE saved)

This initiative requires evaluation of the current system and implementation of appropriate actions necessary to reduce the number of instruments maintained in calibration recall cycle as well as the number of calibrations being performed.

Mapping Improvements Into Skill Categories

Further NASA examination of progress on efficiencies and initiatives will address both the magnitude of the effective FTE improvement, but also the skill categories associated with the improvement.

Process Change Examples

Example 1: WAD Authoring and Validation Environment (WAVE)

WAVE is a good example of how USA is streamlining a paper process that has evolved through a succession of changes intended to incorporate up-to-date technology and consolidate previously existing systems. In response to the numerous changes initiated in the ground operations arena during any given flow, it is necessary to identify the appropriate and applicable technical operating procedure (TOP) and develop a work authorization document (WAD) to be released as the governing document for the work to be performed. WAVE is essentially the automation of this process, providing the engineer with the necessary library of TOPs and related documents, the change request documentation, and a communications “shell” to provide for all proper and necessary coordination and concurrence, maximizing use of intranet/e-mail capabilities. The system is expected to yield a savings of 13 equivalent FTE per year.

Example 2: USA Ground Operations objective is to reduce the number of Configuration Controlled Program Model Numbers (PMN) by 20%

This initiative has set the goal of implementing a revised and streamlined configuration management system for a wide range of critical and non-critical equipment (end-items) used at KSC in ground operations processing and support activity. The de-control of numerous “end-items” will remove some of the red-tape from every day work, such as changing a duplex outlet in an administrative support building not involved in critical operations or tests.

A system is assessed as critical if loss of overall system function or improper performance of a system function could result in the loss of life, loss of vehicle, or damage to a vehicle system (NSTS 22206).
The review employed a risk management approach, retaining critical items and Ground Support Equipment (GSE) under configuration control while identifying items to be de-controlled and eliminating the rigorous process requirements established for flight critical items. All proposed items for de-control will be dispositioned by the GO CCB, as established in SPI BM-326.

The following organizations participate in reviewing de-control proposals:

- USA Resource and Project Management
- USA Design Engineering (Ground Systems, LPS, Communication, and Tracking)
- USA System Engineering (GSE and Facility)
- USA Safety & Reliability
- NASA System Engineering (GSE and Facility)

Regardless of whether a PMN is listed as controlled or non-controlled, it is SFOC's responsibility to keep all drawings current that depict the hardware configuration. The Technical Document Center maintains all USA drawings released at KSC.

<u>Other USA Future/Planned Efficiencies and Improvements</u>

USA/GO has developed an extensive list of other potential process efficiencies and improvements that are listed below. While this report does not discuss or examine these projects, it is anticipated that subsequent reviews will monitor their implementation and resulting efficiencies.

- OPF Tiger Team
- Block Testing
- Electronic Maintenance Manuals
- In-Processing Safety Approvals
- Implement Maximo
- Centralized LAN Administration
- Checks to Processing
- PRACA reduction
- Reduce Problem Reporting (PR) data requirements
- Create Common Specifications and Commodities for all Flight Elements
- Reduce Existing Forms by 50%
- Work Instruction Task Team
- Simplify Safety Requirements
- Reduce OMRS based on mean time between failure
- Reduce V-30 inspection interval requirements
- Scrub non-labor expenditures
- Reduce or eliminate S00000-2 Requirements
- Reduce SPIs by 50%
- Mod Squad FAB of Flight Certified Flight Lines
- Decrease Facilities/GSE Configuration Management Requirements
- Reduce Support Operations Quality Requirements
- Develop Maintenance Modification Process
- Facilitate Electronic Buys on OMIs using EPIC
- Predictive Maintenance
- New Industrial Engineering Group
- Web-Based Deviation Incorporation
- PMI Reduction
- Reduce Certification of Analog Tapes
- Defer LPS Upgrades
- Upgrade Integrated Data Systems Equipment
- Office Automation
- Enhance GSE Maintenance
- Resource Planning
- Calibration
- Eliminate safety WAD approvals for non-hazardous WADs
- ET/SRB Launch Flow Enhancement Team
- Software License Consolidations

2.5.2 Risk Management Concerns

The OSMA review team (as well as other review teams that have reviewed the same issues during the past nine months), fundamentally struggled with the estimated yield of the improvements, the implementation time-lines, the degree of management focus, and the extent of risk management applied to the overall set of improvements and efficiencies. The review team found that a quantitative baseline necessary to measure process improvements is not available at the task execution level and that metrics are not clearly identified. Detailed implementation plans, in many cases are still being developed.

Improvement and efficiency initiative projected yields and implementation dates are largely educated judgement (NASA and USA/GO), making risk management increasingly qualitative in nature. The review team expects that USA can develop more rigor in managing and assessing the risk associated with improvement and efficiency initiative project implementation. USA has a well-defined corporate risk management process that may be doing a better job of estimating technical and safety risks than estimating the business risks associated with many of their proposed efficiency projects. This impression is underscored by the laudable (but perhaps under-powered) bottoms-up implementation of most of the initiatives. A sustained, focused management effort in the next nine to twelve months, with particular emphasis on Group-1 and Group-2 initiatives, will be critical to achieving the advertised efficiency goals and increasing flow-through capability in USA Ground Operations at KSC.

2.5.3 Conclusions

The review team cannot determine that the third hypothesis (below) is true.

Working Hypothesis #3

Process improvements and efficiencies will be implemented in a fashion that will support increased manifest demands expected in mid - late CY 1999.

The issue cannot currently be examined in a deterministic, quantitative fashion. Analysis is currently limited because of the following considerations:

- Limited ability to confirm or accurately estimate implementation date for proposed efficiencies,

- Limited ability to confirm or accurately estimate yield or increased availability of workforce resulting from proposed efficiencies,

- Limited ability to establish the risk associated with achieving efficiency goals or efficiency implementation dates,

- Incursion of unplanned and unscheduled work, particularly in horizontal processing (Orbiter Processing Facilities). It is noted that this is in large part driven by design-center Orbiter modification requirements (not defined at the Launch Site Flow Review) and the high maintenance required by critical Space Shuttle systems such as fuel cells, auxiliary power units (APUs), and the reaction control system (RCS). The high maintenance demands create scheduling uncertainty in ground operations and represent an additional, unquantified risk driver in terms of disassembling and reassembling hundreds of flight critical components to perform unscheduled maintenance.

- Uncertainties in manifest requirements

- Lack of precision in definition of minimum baseline work-flow FTE requirements by skill or certification at the task execution level. Accurate “what-if” planning for future Space Shuttle manifest scenarios requires a knowledge-base (currently unavailable) which provides “resource-loaded” task definition/decomposition, down to the individual task execution level. The review team notes that USA uses an estimate of 525,000 hours FTE for high level planning purposes, given an average flow. USA/GO recognizes the need for higher resolution and is working to refine resource-loading task profiles.

2.5.4 Recommendations

Follow-on Evaluation

In addition to the continued monitoring by the SSP and SMA communities, it is recommended that a follow-on independent assessment be conducted in mid-CY 1999 to evaluate progress in implementing improvement and efficiency initiatives. The team noted that opportunities do exist to achieve efficiencies in administrative and management processes, which support the core work control/review and change control infrastructure. The extent to which USA management, in cooperation with parent corporations, deploys resources and the strength of USA management sponsorship will determine the outcome. A useful follow-on review will in part depend upon the availability of a higher resolution resource-loading model as discussed below.

USA/Ground Operations Baseline Definition

The review team noted that the baseline, minimum number of individuals to perform flows, is unavailable at the task execution level. While the minimum number is implicit in most Work Authorization Documents, the Task Leader judgment and experience is the ultimate work control mechanism. This lack of precision makes capability forecasting difficult. It was noted that USA process baselining activities may resolve this concern by explicitly defining the time and labor force required to perform tasks at the bottom level of the task definition structure. Another benefit of defining minimum resource-loading is reduced dependency on human factors, such as Task Team Leader judgement, which may or may not always be as experienced and skilled as the present workforce.

Monitoring Ground Operations as Capability Approaches Saturation

At some point in the future, the International Space Station (ISS) launch and build demand will drive the KSC Ground Operations organization into a saturated state. If the work control, work review, and change control processes are as good as we believe they are, they will not allow safety to be compromised. Nonetheless a saturated USA/GO organization should be monitored carefully, with particular attention devoted to human factors.

Monitoring Impact of Short-Term Solutions in the Event Efficiencies are not Realized

In the event that planned improvements and efficiencies do not succeed, USA has contingency plans which offer short-term solutions. USA Ground Operations (GO) has the capability and flexibility to address specific short-term staffing shortages through borrowing and lending certified skilled workers between facilities (i.e., among Orbiter Processing Facilities, the Vertical Assembly Building, and Hazardous Processing Facilities). This practice can continue until the GO system reaches saturation (three or four Space Shuttles in flow). Other contingencies include borrowing from GO facility and infrastructure staff, and possibly parent companies (Lockheed-Martin and Boeing). If necessary, laid-off workers can be rehired and/or new employees could be recruited. NASA management needs to closely monitor short-term management "work-arounds" that may affect the long-term capability and stability of the ground operations and facility infrastructure.

3.0 NASA Kennedy Space Center (KSC) Safety and Mission Assurance (SMA)

3.1 Introduction

The role of this review team was to determine the ability of the KSC/SMA Office to support a one-a-month flight rate of the Space Shuttle. The award of the Space Flight Operations Contract (SFOC) to United Space Alliance (USA) resulted in a major shift of responsibilities away from the civil service workforce, with the contractor assuming responsibility for the day to day operations. Because of this shift, the role of the KSC/SMA organization has moved from oversight of the total process to surveillance using both insight and oversight methods. This changing role is a continuing activity for the foreseeable future. Therefore, the review team chose to begin its activities by defining the interfaces and interactions between the KSC/SMA organization and USA. The process for the assessment is shown in Figure 3.1-1.

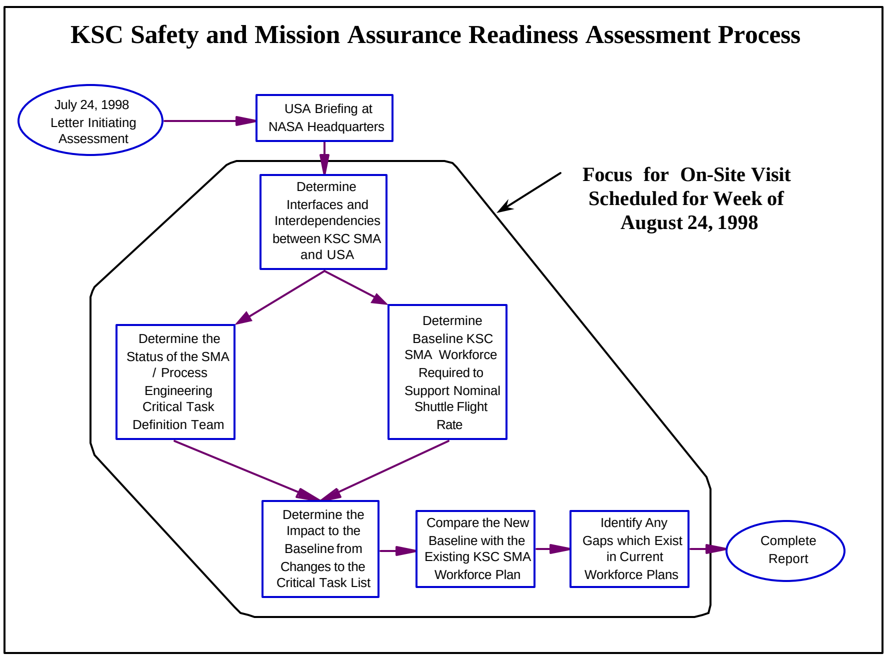


Figure 3.1-1 KSC SMA Readiness Assessment Process

The initial focus of the assessment was aimed at fully understanding all of the interfaces and interdependencies between the KSC/SMA organization and USA in support of Shuttle processing. The current assessment involves USA-SMA personnel to the extent that is necessary for understanding their perspective on the effectiveness and capabilities of the KSC/SMA organization. The next activity in the assessment process involved understanding the work of the SMA/Shuttle Processing Critical Process Review Team. This team is addressing the “in-depth observations” (IDOs) that are required to be performed, but which were not identified as mandatory. These IDOs are of critical tasks within a procedure that must be performed correctly to ensure personnel safety, safety of flight, or facility/equipment safety. The critical process team is not addressing the Government Mandatory Inspection Point (GMIP) reduction. That reduction is occurring under a separate process. However, once GMIPs are reduced to the determined level, they will be folded into the list of critical processes. These GMIPs are identified as requiring inspection instead of IDOs. If a GMIP is required on an activity also requiring a safety or process engineering IDO, then a single NASA individual could be assigned to the perform the IDO and inspection.

This single-inspector approach would reduce the overall NASA head count involved in inspection or observation of tasks.

This assessment includes looking at changes to the number of critical tasks, which meet the criteria for IDO or inspection. Criteria used for considering whether to retain the activity as a critical task requiring IDO or inspection were developed, as well as processes by which a sharing of work, leading to a "one-badge NASA will take place.

Paralleling the work of the Critical Process Team, KSC/SMA should determine a workforce baseline for Shuttle processing. This baseline should include all Shuttle related tasks. It should also distinguish between tasks independent of flight rate and those that dependent on the number and rate of flights. This will lead to an understanding of the impact of a one-a-month flight rate considering the interfaces, interdependencies, and KSC-SMA/Shuttle Processing directorates sharing of work. Changes to the baseline will be identified from the changes to the Critical Process Definitions, as well as from an increase in the flight rate.

After a new baseline is determined, an assessment of how these changes impact the existing and planned KSC-SMA workforce will be performed. To accomplish this, objective evidence of workforce allocation and usage planning within the KSC/SMA organization must be provided. It will be necessary to develop an assessment to:

- look at the depth and realism of planning,
- analyze objectives,
- evaluate processes used,
- define metrics by which KSC-SMA measures how well they are doing, how they assess the risks for any changes (and what those risks are),
- evaluate controls that are in place, planned, or needed, and the
- assess the level of insight/oversight activity required

Kennedy Space Center Safety and Mission Assurance Organization

The Safety and Mission Assurance Organization has an allotment of 236 civil servants during FY 1998, including all administrative personnel, safety and quality engineers, and specialists. This number is scheduled to be reduced to 226 in FY 1999. Currently, the organization is below the FY 1999 total allocation. However, some adjustment of the skill mix is continuing. In addition, there is an active effort to bring in new personnel to the safety organization to augment attrition, while maintaining a level below the allotment. The KSC/SMA organization is shown in Figure 3.1-2.

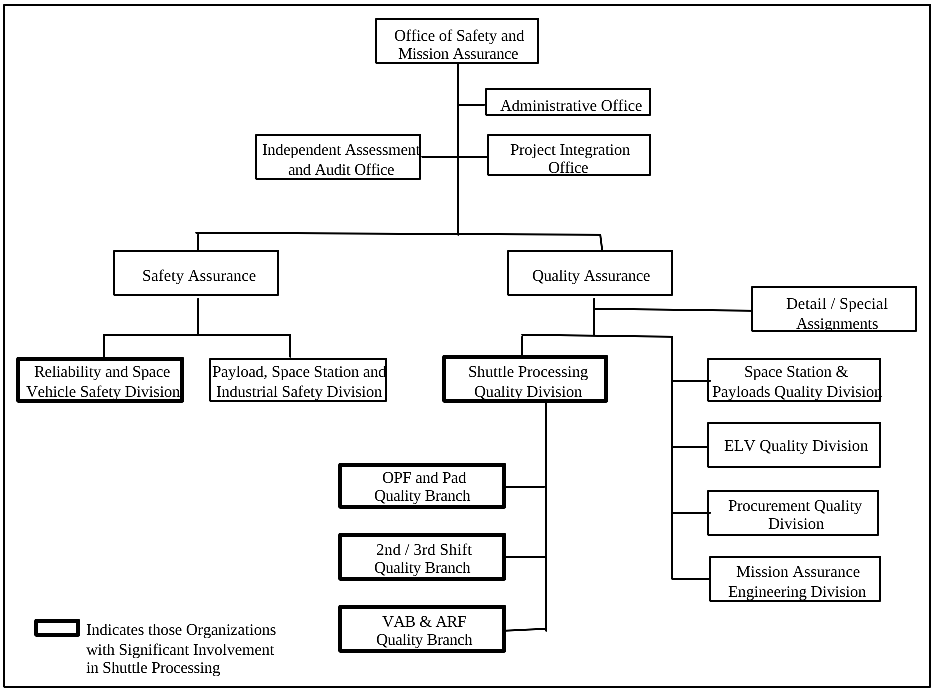


Figure 3.1-2 KSC/SMA Organization

3.2 On-Site Assessment

The initial on-site visit by the team was held August 24-26, 1998. During this visit interviews were held with the Director of Safety and Mission Assurance for KSC, the Directors' of Safety Assurance and Quality Assurance, the Head of the Project Integration Office, the Independent Assessment and Audit Office, and numerous other administrative and technical personnel.

In the past each division in the SMA organization had a significant pool of resources from which to draw to perform the activities requested by their customers. This pool of resource was sufficient to allow extensive in-line support of the safety and quality functions at KSC. This resulted in a reactive mode of operation in response to requests for support by program offices at KSC, instead of a deliberate requirement assessment and resource planning activity. The transitioning of Space Shuttle ground operations to SFOC/USA, and the resulting reduction in personnel already implemented and those planned by the year 2000, has forced the SMA organization into a state of significant change. The two primary directorates in the SMA organization, Safety Assurance and Quality Assurance, are approaching their tasks from slightly different directions. This causes some difficulty in integration of planning functions between the two directorates.

During the on-site visit, individuals being interviewed raised several issues. These ranged from concerns for potential adverse program impact to suggestions that might improve the ability of SMA personnel to understand and prepare for an increased flight rate. A specific concern relevant to KSC/SMA's ability to support an increased flight rate includes:

- The differences that exist between the contractor's and NASA's metrics, for example, metrics for first time quality.

This concern was addressed during subsequent visits and interviews. It is the opinion of the assessment team that care should be taken not to force all metrics to measure the same thing. We need to understand any differences, and assure that we are not inferring the same meaning to different sets of data. However, forcing the same measurement could lead to complacency where we fail to identify important leading indicators of safety and/or quality problems.

A specific suggestion discussed:

- The use of simulation/tabletop planning of critical procedures and hazardous operations prior to the initiation of an entire Shuttle processing flow. This would be beneficial to the SMA organization and the processing organization to assure proficiency, and to identify any process changes incurred by OMRSD scrubs, GMIP removal, and implementation of process efficiencies.

This suggestion was based on a concern that proficiency may have suffered with the lack of shuttle flights over the past few months, and might suffer in the future if the ISS assembly schedule continues to slip. A reduced proficiency, coupled with the proposed increase in flight rate, could cause potential safety and quality problems to occur. A simulation or tabletop planning exercise would be beneficial in pointing out potential problems and allow them to be addressed prior to the occurrence of the problem. An additional benefit would be that such an exercise would be valuable in the identification of other improvements and efficiencies that could be made to the processes.

<u>Interfaces</u>

The Safety Assurance Directorate has produced a white paper on potential reorganization strategies to meet the changing role that it has been assigned. The white paper calls for realigning the existing two divisions by safety specialist and safety engineers instead of by the current program oriented alignment. An additional option that the white paper suggests is the development of a support service contract that could perform specific tasks such as supporting the Payload Safety Engineering Reviews. The Safety Assurance Directorate has also been increasing the number of personnel assigned to support Space Station processing activities, and has advertised for several vacant positions. Since 1996 the Safety Assurance Directorate has lost 19 safety engineers and 12 safety specialist. This loss represents approximately 30 percent of the organization. As a result of the transition of in-line safety functions to contractors, the Safety Assurance Directorate is moving towards an insight role of the contractor activities. The primary interfaces between the Safety Assurance Directorate and the Space Shuttle program is in the Reliability and Space Vehicles Safety Division. During the months of May, June, and July 1998, an average of 16 FTE persons charged their time to the Shuttle program.

The Quality Directorate has a significant ongoing effort to reduce the number of Government Mandatory Inspection Points (GMIPS) for the Shuttle. In addition they are working with the Critical Process Team to consolidate overlapping functions between personnel from Safety, Quality, Process Integration, and Process Engineering. Significant reductions have already been made to the number of GMIPs. The next process flow for the Shuttle will reflect a reduction to approximately 8,500, which is down from an average of approximately 22,000 per flow. Expectations are that the number can be eventually reduced to between 5,000 and 6,000. The Quality Assurance Directorate and the Space Shuttle program have several interfaces including the Shuttle Processing Quality Division, the Procurement Quality Division, the Mission Assurance Engineering Division, the Orbiter Maintenance Down Period (OMDP) activities, and the Checkout Launch Control System (CLCS) activities. During the months of May, June, and July 1998, an average of 102 FTE from the Quality Assurance Directorate charged their time to the Shuttle program. The primary interface is in the Shuttle Processing Quality Division.

In addition to the two divisions mentioned above the Independent Assessment and Audit Office is also involved in Shuttle activities. This office serves as technical advisor to the SMA Director during launch countdowns and provides the KSC-SMA independent assessment function that supports the SMA Prelaunch Assessment Review (PAR) process. Independent assessment personnel also act as technical advisors to assist in review and assessment of problem areas to assure that shortcuts are not being taken. The office is currently exploring ways that they can better interface with the OSMA, Independent Assessment Office at the Johnson Space Center for Shuttle-related assessments. Although the Independent Assessment and Audit Office serves a useful function for the Shuttle Program, they are not in a serial processing path. This makes their activity relatively independent of the Shuttle flight rate.

Figure 3.2-1 shows the interfaces between the KSC/SMA organization and Shuttle processing. The figure also points out those areas that are dependent on Shuttle flight rates and those that are independent of flight rates.

In addition to the organizational interfaces listed above, there are at least three joint meetings each month involving the KSC/SMA Director and the SMA Director for USA. These include a scheduled face-to-face between the two directors, a KSC/SMA managers meeting participated in by the USA SMA manager, and a USA managers meeting participated in by the KSC/SMA Director.

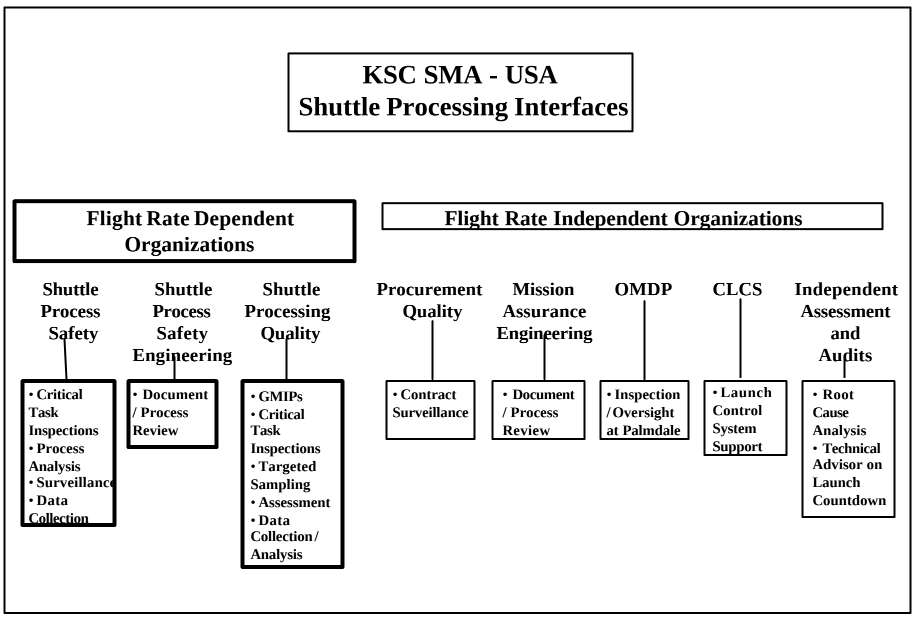


Figure 3.2-1 Shuttle Processing Interfaces

Critical Process Definition

The Critical Process Definition Team consists of personnel representing the Shuttle Processing Directorate, Process Engineering, Process Integration, the Safety and Mission Assurance Directorate, the Reliability and Space Vehicle Safety Division, and the Shuttle Processing and Quality Division. For the purpose of this effort, critical processes are defined as "A group of related activities which must be performed correctly to ensure processing personnel, flight, or hardware/facilities/GSE safety." The team is reviewing all candidate critical tasks to determine if they are NASA managed tasks, require "In-depth Observation (IDO) or inspection," or may be assessed using other surveillance tools. Tasks that fall under the NASA managed activities include launch, landing/recovery, and out-of-family activities. These activities will continue to remain under NASA oversight and control. Tasks that are non-critical have been, for the most part, turned over to USA personnel for performance and will be the subject on on-going surveillance from an insight mode of operation. IDO tasks are those where government personnel directly observe the contractor during the performance of work. All existing safety critical tasks, GMIPs, and critical engineering tasks are candidates for consideration. The Critical Process Model is shown in Figure 3.2-2.

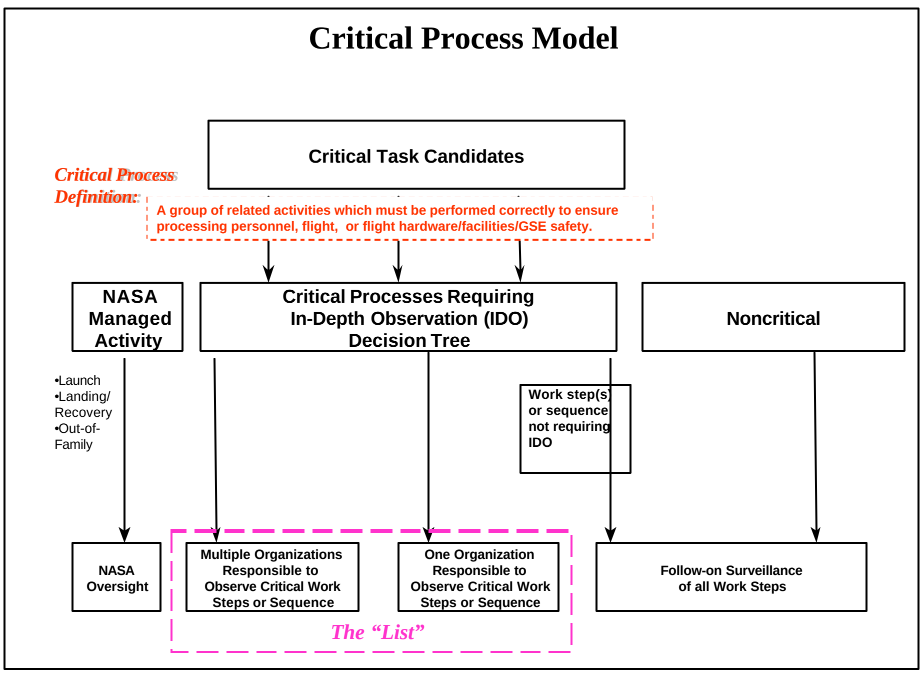


Figure 3.2-2 Critical Process Model

The determination of critical processes requiring IDO or inspection is made based on a decision tree. One output from the team activities is a determination of whether a single organization or multiple organizations are required to perform the IDO. A goal of the Critical Process Team is to reach a one NASA badge concept where whoever is present and in place for NASA performs all of the work required. While this may be a good goal it is impractical for all activities. There are some activities where the physical task is performed in a different location or time than the task test and therefore requires more than one person, or laws, policies, procedures require multiple organizations to observe or inspect the activity. The decision tree used by the team is shown in Figure 3.2-3.

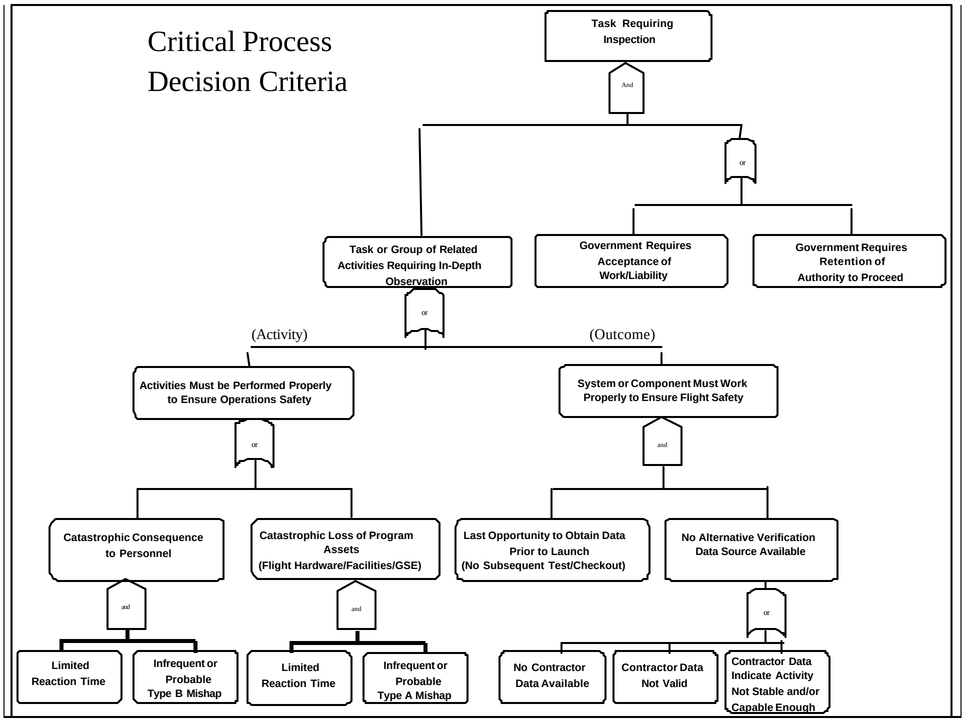


Figure 3.2-3 Critical Process Decision Criteria

The Critical Process Team has done an excellent job of defining and identifying its processes and decisions models. They have formalized the process and are doing a qualitative assessment of risks associated with each decision. Full documentation of the results of the processes are also maintained. They have involvement from all organizations concerned with the activities, although the level of participation by each of the organizations varies from proactive to passive support in completing the mission of the team. Within the SMA organization the Reliability and Space Vehicle Safety Division has taken a leading role in the identification of activities for the critical task list, as well as defining those activities that must be done by a safety professional.

Unfortunately the team has not progressed as rapidly through the process as they had hoped. There appear to be two major activities left to complete. First is the final identification of the activities requiring IDO or inspection. Second is the determination of which organization will be in place to perform the one-NASA-badge surveillance of the task. The organization, which defined the need for the IDO, will be the responsible organization for assuring the work is performed and providing whatever training or tool needed to perform the IDO. Completion of this activity is currently scheduled for the end of the calendar year.

The Reliability and Space Vehicle Safety Division is taking a strong proactive position in defining how they will operate in an insight mode. Working with the Critical Process Team they have defined each of the critical processes as a level 1,2 or 3 process. Level 1 and 2 processes are those that require safety data, but recognize that the information can be obtained by someone other than a safety professional. A Level 1 process would required the use of a checklist while a level 2 process would require the individual to receive some degree of training to perform the function. Level 3 processes are those that require a safety professional to accomplish the activity.

Shuttle Baseline SMA Workforce Requirements

A major concern of the review team was the lack of a quantitative baseline assessment of workforce requirements of the part of the KSC/SMA organization. Both the Safety Assurance and the Quality Assurance Directorates were performing extensive planning exercises. However, the planning was reactive in nature in response to either workforce levels currently charging to programs, or to workforce allocations in future years. A bottoms-up assessment of program requirements based on projected workflow has not been performed. Personnel in both organizations clearly understand the elements of work desired or requested by the projects. However, the lack of a qualitative analysis, coupled with the incomplete nature of the Critical Task Definition Team, makes it impossible to assess perturbations to the KSC/SMA workforce that will result from an increased flight rate.

SMA Workforce Planning and Gaps

As noted above there are no quantitative baseline workforce numbers from which gaps caused by an increased flight rate can be determined. A second concern is the integration of planning processes between the Safety Assurance and Quality Assurance Directorates. During the interview with personnel from the Quality Assurance Directorate the review team repeatedly heard that there was no workforce-planning model available for them to use for qualitative workforce analysis. The quality representative to the Critical Task Definition Team has chosen not to identify any critical quality tasks, leaving that definition to Safety and Process Engineering. The Quality Assurance Division had a significant planning exercise geared to the GMIP reduction process and had developed a “Big Picture” approach to the KSC Quality Assurance Program. This Big Picture approach for their Quality Assurance Program uses both insight and oversight mechanisms to perform the quality surveillance role. The conceptual approach used for this planning is shown in Figure 3.2-4.

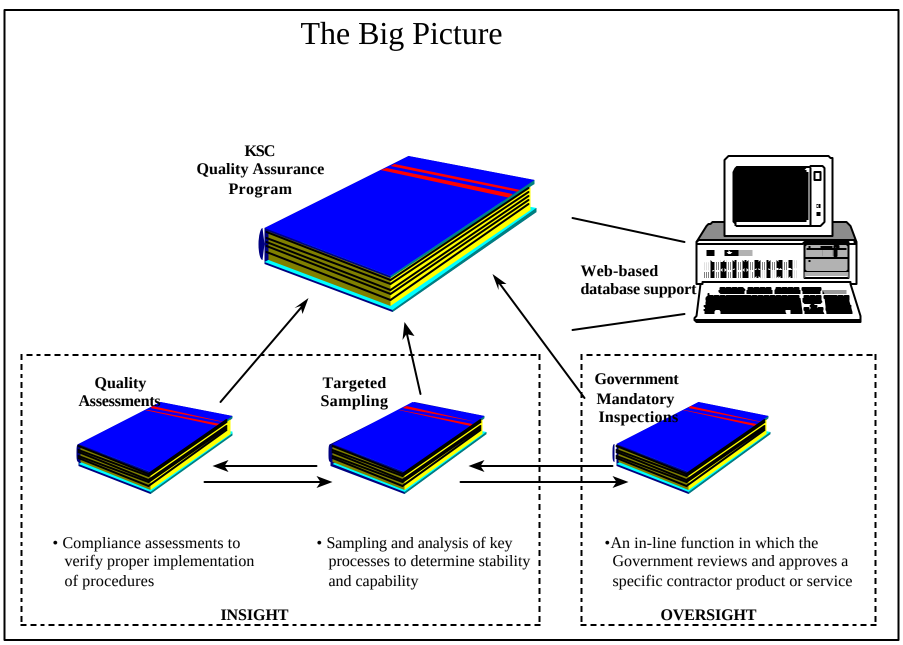


Figure 3.2-4 The Big Picture

The Safety Assurance Director temporarily reassigned several safety specialists and hired others internally from the Shuttle Processing area to relieve critical workforce shortfalls in the processing of Space Station hardware. The Reliability and Space Vehicle Safety Division has identified its tasks at three different levels of criticality based on the level of training necessary to perform the function. They are looking at a mixture of insight and inspection to perform the functions. The Division managers believe they will be able to perform all of the level 3 tasks within the current workforce ceilings. However, there is no quantitative data to support this belief.

The two SMA Directorates use a different basis for planning workforce needs and have other differences in approaches that extend to the language used to describe processes. Each organization has different uses and meanings for terms such as insight, oversight, and surveillance. If KSC is going to achieve its goal of a one-NASA-badge then there will have to be significant integration of techniques and methods.

Within the past few months a new Director has been named to lead the Quality Assurance Directorate. Since the on-site visit the Director has undertaken an analysis of the Shuttle workforce requirements supporting surveillance of process tasks. The rough results of the analysis, as well as the process used, were faxed to members of the review team on October 7, 1998. A review of the process followed in the analysis indicated a sound, logical approach was used in the identification of workforce needs. The analysis was based on an Orbiter processing flow of 85 days and 8 launches per year. These results are not directly scalable to higher or lower flight rates but the process can be applied for any flight rate due to the fact that only three Orbiters are in processing at any given time, which is constrained by available facilities. The significance of the analysis process goes well beyond planning for the Shuttle flight rate concerns. When applied across the board for all projects it provides a baseline by which to assess the impact of changes to work requirements, as well as providing a basis on which to request additional support or resources from Center management.

3.3 KSC/SMA Status

The role of this review team is to determine the capability of the KSC/SMA Office to support an increased flight rate of the Space Shuttle. Four initial goals were established in order to accomplish the task.

1. Fully understand the interfaces and interdependencies between the KSC/SMA organization and USA in support of Shuttle processing.

Interfaces from both a management and technical level are defined. Both the Safety Assurance Directorate and the Quality Assurance Directorate have significant interaction with Shuttle processing. Approximately 102 Full Time Equivalent from the Quality Assurance organization and 16 from the Safety Assurance organization are currently charging time to the Shuttle program. These numbers include management and administrate personnel. Within these two organizations there are a total of eight division or office level activities that have significant Shuttle-related activities underway. Of these only the Shuttle Process Safety, the Shuttle Process Safety Engineering, and the Shuttle Processing Quality organizations perform flight rate dependent activities.

2. Understand the work of the SMA/Shuttle Processing Critical Process Team and its impact to Shuttle workforce requirements.

The Critical Process Team has done an excellent job of defining and identifying its processes and decisions models. Unfortunately the team has not progressed as rapidly through the process as they had hoped. There appear to be two major activities left to complete. First is the final identification of the activities requiring IDO or inspection. Second is the determination of which organization will be in place to perform the one-NASA-badge surveillance of the task.

For in-depth government observations USA will have to include these activities in the existing "Call System" for government personnel used on GMIPs.

3. Define the KSC/SMA baseline for Shuttle processing.

A major concern of the review team was the lack of a quantitative analysis on which to base an assessment of readiness. Since the on-site visit the Quality Assurance Director has undertaken an analysis of the Shuttle workforce requirements. The rough results of the analysis, as well as the process used, were faxed to members of the review team on October 7, 1998. A review of the process followed in the analysis indicated a sound, logical approach to the identification of workforce needs. The results must still be integrated with the Safety Assurance Directorate at the KSC/SMA level to provide a basis of overall workforce requirements. If KSC is going to achieve its goal of a one-NASA-badge then there will have to be significant integration of results between SMA organizations as well as integration of analysis techniques and methods.

4. Assess any gaps between the baseline workforce and requirements imposed by an increase flight rate.

As noted above there is no quantitative baseline workforce numbers from which gaps caused by an increased flight rate can be determined.

There is a potential that the attitude of "Schedule drives Safety" will return. No evidence was found of this happening to date. There is a need to develop some leading metrics that will give indication that schedule may start driving safety (Number of waivers, close calls, and quality escapes).

3.4 Conclusions and Recommendations

Although no objective evidence was found to indicate that the work requirements will have any adverse impact on safety or quality, the KSC/SMA planning process is not sufficiently mature to provide evidence that the increased flight rate can be supported within current workforce ceilings. The following specific issues lead to this conclusion.

- There are no quantitative, requirement based, workforce numbers to provide a baseline from which gaps caused by an increased flight rate can be determined.
- The Critical Process Team has not yet completed its work. Consequently the results defining the reductions in workforce requirements based on reduced critical tasks requiring IDO or inspection (GMIPs) are not available for use in further analysis.
- The reduction in GMIPs is not yet completed for integration into the Critical Process Team process.
- No integrated analysis process is in place from which a quantitative analysis of workforce requirements can be made.

The Critical Process Team has done an excellent job of defining and identifying its processes and decisions models. There appear to be two major activities left to complete. First is the final identification of the activities requiring IDO or inspection. Second is the determination of which organization will be responsible for performing the one-NASA-badge surveillance of the task. Since the on-site visit the Quality Assurance Director has developed a workforce analysis process based on a nominal 80 day Shuttle process flow. This analysis process could be used by all KSC/SMA organizations. This would provide a basis for integrating the workforce requirements, and determining areas where cross training or other forms of cooperation could lead to further gains in efficiency and expansion of the one-NASA-badge concept for SMA work. This process should provide a continuous improvement tool for the KSC/SMA organization with positive impacts beyond the immediate assessment of Shuttle readiness for an increased flight rate.

Several recommendations for improved efficiency and an enhanced safety posture resulted from the assessment.

- Leading metrics that will give an advance indication that schedule is starting to drive safety should be developed. For example: Number of waivers, close calls, and quality escapes, etc.

- With the one-NASA-badge concept IDO and inspections (GMIPs) of critical tasks, consideration should be given to including IDO requirements in the existing "Call System" for all government interfaces similar to that currently used on GMIPs.

- The use of simulation/tabletop planning of critical procedures and hazardous operations prior of the initiation of an entire Shuttle processing flow would be beneficial to both the SMA organization and the processing organization.

- Care should be taken to assure that we are not inferring the same meaning to different sets of metrics. However, we also need to assure that we do NOT remove independence by forcing all organizations to measure the same thing.

Because of the incomplete nature of the information on which to base this assessment, it is recommended that the KSC/SMA organization notify the Office of Safety and Mission Assurance when it has completed the Critical Process Team effort and the workforce analysis planning. At that time a follow-on assessment should be performed to assess the completeness of the activity.

4.0 NASA/SFOC Flight Operations

The Flight Operations Review team of the Process Readiness Review (PRR) performed a high-level assessment of the readiness of both NASA and Space Flight Operations Contract/United Space Alliance (SFOC/USA) flight-critical processes to safely accommodate an increased annual flight rate at the current staffing levels and skill mix. This review was based on daily interaction with the Space Shuttle Program (SSP) and the SFOC/USA. In addressing the relative readiness of Flight Operations Processes, which are located at the Johnson Space Center (JSC), the Flight Operations Review Team had met with NASA Technical Management Representatives (TMRs) and SFOC/USA Associate Program Managers (APMs) for Orbiter Project, Systems and Cargo Integration Project, and Flight Operations Project. The review team made extensive use of presentation material from recent Program Manager's Reviews, Stratical (strategic/tactical management) Forums, and other SSP meetings in which OSMA staff regularly participates. The Review Team's discussions with TMRs and APMs took place on September 30 through October 2, 1998, and focused on acquiring answers to following questions:

- What are you doing, in the way of process improvements or enhancements, to prepare for a higher flight rate?
- What are you doing to maintain proficiency of the work force during the current lull in the Space Shuttle manifest and the projected lull between January and May 1999?
- How do you identify and account for critical skills in your organization and how do you prepare for attrition?
- What concerns, if any, do you have relative to the manifest, both in the near term and in the long term?

4.1 Orbiter Project Readiness Assessment

The Orbiter Project functions comprise four major areas: pre-launch and mission support; sustaining engineering, including upgrade development; manufacturing of the External Tank (ET) half of the 17-inch umbilical disconnect; and overall project management. In comparison to Ground Operations, the SFOC/USA Orbiter Project reduced its work force by approximately 14%, or just under 100 positions. All of the positions removed were at Boeing North American [now known as Boeing, Reuseable Space Systems (Boeing-RSS)] and either functioned as direct mission support or Orbiter sustaining engineering. There were no positions eliminated at the SFOC/USA project management level. The majority of the positions removed were found to be in the sustaining engineering area, which is not considered flight-rate sensitive. The staff removed from these positions is not completely out of the reach of the SSP; nearly all have been reassigned to other programs in Boeing-RSS and can be recalled to meet surge demands as necessary.

The Orbiter Project is aggressively working several initiatives that are needed if the current work force (minus projected, normal attrition) is to support an increase in annual flight rate in the future. The majority of the initiatives are focused on streamlining critical operations processes in the sustaining engineering arena. This includes becoming more efficient in: production cycle time, especially in the ET umbilical manufacturing component; flight readiness engineering in support of USA and SSP reviews; and support to the on-going process flows at KSC. Metrics have been developed to baseline the effort spent in each of these areas in preparation to assess the efficiencies gained as the initiatives are implemented in the next year.

In each of the areas addressed in the Process Readiness Review, a common challenge was identified in the area of managing and maintaining critical skills needed to meet the overall SSP mission. The skills held by NASA and contractor work force are in high demand in other areas of the aerospace and information technology industries. SFOC/USA and Boeing-RSS are keenly aware that it is necessary to maintain the Orbiter corporate knowledge base so that Orbiter systems may be maintained and upgraded to support missions well into the next century. In the past, NASA and Boeing-RSS (formerly Rockwell) each retained subsystem managers and engineers for each major Orbiter subsystem, providing some measure of redundancy in the collective work force. With the transition of subsystem management responsibility to SFOC/USA and Boeing-RSS, NASA is reassigning the former subsystem managers and subsystem engineers. As this transition is completed, the final outcome will be a single-string subsystem manager capability in most of the SFOC/USA Orbiter functions.

Although this is not considered a problem today, SFOC/USA and Boeing-RSS have an ongoing challenge to maintain sufficient proficiency in the work force to overcome normal promotions and attrition in the management and engineering ranks. To counter this, SFOC/USA and Boeing-RSS have a plan in place to meet surge demands, as necessary. As stated above, most of the staff removed from directly supporting the Orbiter Project have been moved to other positions within Boeing-RSS and can be accessed as needed to support demand. A process is in place to temporarily rehire retirees for short periods of time to meet the need; in 1998, fifteen such retirees were brought back to assist in solving certain critical problems. A formal mentoring and job rotation process has been established for younger staff members to expose them to a greater variety of subsystems and to provide the opportunity to gain needed training from more experienced staff members. Additionally, SFOC/USA and Boeing-RSS have access to Boeing corporate resources to address critical problems when presented. Although a comprehensive database of Boeing corporate talent is on-line, the need to use this resource has yet to be tested.

The Flight Operations Review Team finds that the Orbiter Project Team, comprising NASA, SFOC/USA, and Boeing-RSS, are, with one exception, able to surge to a flight rate of eight flights per year. To gain the ability to sustain a higher annual flight rate, the Orbiter Project Team must continue to manage the critical skills necessary meet the projected demand and augment critical skills with Boeing corporate resources as needed. A concern identified by the Review Team relates to the instances when multiple anomalies are presented in a single subsystem, as has occurred many times in the past. The SFOC/USA and Boeing-RSS team believe that they will be capable of supporting analysis and resolution of multiple anomalies in a single subsystem by accessing Boeing corporate resources; however, this capability has not yet been tested. In addition to the staffing challenges, the production of ET umbilicals must be made more efficient to meet a rate of eight flights per year and beyond. Current production levels are just keeping pace with demand. ETs are being shipped from the Michoud Assembly Facility without installed umbilicals; an undesirable situation.

4.2 Systems and Cargo Integration Project Readiness Assessment

The Systems and Cargo Integration Team is responsible for all engineering analyses that result in certifying the integrated Space Shuttle Vehicle for all flight and mission profiles. Integration processes are managed by SFOC/USA and performed by Boeing-RSS. The NASA Integration staff performs surveillance of SFOC/USA and Boeing-RSS processes through insight and oversight processes. The overall integration function is divided into key areas: Systems Integration, which addresses the assembled vehicle; Payload and Cargo Integration; SSP-to-ISS Integration; Verification Management; and Program Information Systems Integration. As in other areas, NASA has transitioned the management of Systems and Cargo Integration tasks to SFOC/USA; all transitions were completed by mid-1998.

Staff reductions made earlier this year in the SFOC/USA and Boeing-RSS Systems and Cargo Integration areas were minimal, numbering less than 25. At the current level, Systems and Cargo Integration staff can support up to eight flights per year. SFOC/USA and Boeing-RSS have several initiatives in work to reduce analysis cycle time to enhance their capability and support a higher flight rate. Key among these initiatives is a digital mock-up environment that enables analysts from all disciplines (thermal, structural, electrical, etc.) to conduct specific analyses in parallel. Other tools, including electronic development and delivery of reconfiguration drawings will also shorten the cycle time from flight to flight. The goal is to reduce the reconfiguration engineering time by 50% from the existing baseline in 1997 by the end of FY 2000, and indications are that the Integration Team is well on its way in meeting that goal.

The current Systems and Cargo Integration analysis processes are the constraining factors that define the flight rate capability. The flight analysis template now in place can be anywhere from 18 to 24 months in length, depending on the complexity of the payloads and mission profile. This is clearly demonstrated by the fact that even though the FY 1998 and FY 1999 flight rates were at five flights, the overall integration workload did not decrease due to the long lead time needed to develop the integrated certification for each flight. Recent manifest changes have caused certain analyses to be scrapped and re-performed due to changes in seasonal conditions that affect both launch and on-orbit loads. Changes in assignment of payloads to different vehicles also cause analyses to be re-performed due to the subtle differences among the Orbiters. Additionally, analysis of Shuttle upgrades and Orbiter enhancements that have been proposed or that are in work, require significant analysis to meet certification requirements. In summary, the Systems and Cargo Integration workload did not decrease commensurate with the flight rate and, in some cases, actually increased.

Critical skill retention has been an ongoing concern for SFOC/USA and Boeing-RSS in the Systems and Cargo Integration areas, as in other areas. The planned consolidation of the Boeing-RSS engineering function with the Boeing Expendable Launch Vehicle (ELV) engineering function at the Boeing-Huntington Beach facility is anticipated to provide greater workforce depth and stability. Tools and techniques used to perform required analyses for SSP are similar to those used for ELVs for payload integration and mission loads. For this reason, the combined Vehicle Integration work-force pool that will ultimately reside together at the Boeing-Huntington Beach facility can benefit all programs by sharing critical skills as needed to cover all demands on all programs. SFOC/USA has established a salary-grade update process based on an annual market survey to maintain salaries at competitive levels. The foundation for this process is a Critical Skills Retention Fund that is budgeted each year to provide incentive for the staff to stay with the program.

The Flight Operations Review Team finds that the NASA, SFOC/USA, and Boeing-RSS Systems and Cargo Integration Team have concerns for the future manifest, both near- and long-term. These concerns are based in part on the uncertainty of the ISS deployment schedule and the effect that continual manifest change will have in meeting their goals for improved cycle-time. In the long-term, there are concerns with the lack of post-ISS deployment missions thus far identified. These concerns, however, are considered by the Flight Operations Review Team to be beyond the control of the Systems and Cargo Integration Team.

The Flight Operations Review Team finds that the NASA, SFOC/USA, and Boeing-RSS Systems and Cargo Integration Team are actively planning for the future and flight rates up to and above ten flights per year. This is demonstrated by initiatives, both implemented and in work, to reduce certification analysis cycle time and to increase the efficient use of the combined work force. The ultimate consolidation of the Boeing-RSS SSP and ELV integration work force at the Boeing-Huntington Beach facility will enhance the capability to meet unplanned peaks and valleys in future manifests. The commitment by SFOC/USA to retaining critical skills is demonstrated by the budgeted Critical Skills Retention Fund and the continual management attention paid to this concern.

4.3 Flight Operations Project Readiness Assessment.

The Flight Operations Project Team comprises the NASA Mission Operations Directorate and SFOC/USA Flight Operations. Flight and mission operations continue to be a NASA-managed function; however, all other functions of Flight Operations are shared with, or directly tasked to the SFOC/USA Flight Operations staff. Overall, flight operations functions include: flight and mission operations; flight design, including payload operations; astronaut training and certification; flight controller training and certification; reconfiguration of flight software for each mission, including modifications for payload-unique functions; and customer mission support. The Flight Operations Project was not impacted by the SFOC/USA reduction in staff that was introduced in January 1998. Cost reductions needed were offset by adjustments in task content and re-allocating uncommitted funds. In FY 1998, SFOC/USA Flight Operations has increased staff in preparation for the expected workload with ISS.

The Flight Operations Project Team currently has sufficient facilities and staff to support a flight rate of eight missions per year. An extensive overhaul of most Flight Operations Project processes, called "Reinventing Mission Operations" will provide the capability to reduce process cycle time and support higher annual flight rates in the future. Key enabling factors to reduce the overall Flight Operations process cycle time are:

- Ability to remove the payload operations portion of the vehicle software in order to reduce the need to re-configure software for similar missions. This will be most beneficial when flying repeated missions to ISS.
- Standardization of performance envelopes, thus reducing the need for extensive flight re-design for similar missions.
- Verification of flight software at incremental stages of development instead of a full-up verification at the end. This will reduce the need for repeated verification of the full flight software package when errors are found in specific areas of the software.
- Flight-similar training, providing the capability to reduce the number of mission-specific training modules currently required for each mission and enhance flexibility in the training schedule.
- Streamlining of real-time mission execution by providing common workstations and tools for all flight control staff.

As in the case of the Systems and Cargo Integration Project, the flight preparation template for flight plans and astronaut/flight controller training is approximately 12-18 months, thus preparation for future flights is already underway. The continuous rescheduling of the manifest has had an adverse impact on the Flight Operations training processes. This is due to the fact that certain certification requirements require certain training to be accomplished within a specific time prior to the mission. Moving missions further out in the calendar results in the need to repeat some training. Training process efficiency is adversely impacted by manifest changes; the effectiveness of the training process is not impacted. In addition to training, flight planning is adversely affected by moving mission payloads from one Orbiter to another. As this occurs, flight planning must also be assessed and adjusted as necessary.

In general, proficiency in many areas is not affected by flight rate. The areas that are flight-rate related (astronaut training instructors and flight controllers) maintain proficiency through support of the manifest and ongoing generic and flight-specific training. The reduced flight rate last year and the projected flight rate this year has provided the opportunity for additional training through simulations on actual mission control center consoles because the facility is not tied up with mission operations.

Of all of the projects reviewed, the Flight Operations Team finds that the Flight Operations Project has the best accounting of critical skills needed to perform their mission. This capability is not new. Critical skills identification and accounting has been a long-standing process because the skills needed required specific training; these skills readily available in the aerospace industry. Critical skills staffing and certification is accurately tracked to maintain minimum requirements. A special compensation package is provided to those who maintain certification of their critical skills. Attrition is identified and planned for in staffing profiles and certification requirements.

The Flight Operations Review Team finds that the Flight Operations Project is planning for the future operations environment by reinventing the way they do business. Flight Operations has a clear understanding of the critical skills required to perform their mission and has the process in place to offset attrition of critical skills in the future. The Flight Operations Project continues to have concerns about the instability in the manifest, as do others. Continual changes and delays of missions in the manifest results in inefficiency by requiring time-sensitive training to be repeated. With changes planned in Flight Operations processes through the reinvention effort, the Flight Operations Project should be able to increase their annual flight-rate capability beyond their current seven-to-eight flights per year.

4.4 Summary

Overall, the three projects assessed in the Flight Operations Review portion of the Process Readiness Review can support a manifest requiring a rate of eight flights per year. Challenges continue in the area of critical skill retention; however, each project has a plan in place that is actively addressing this challenge. Initiatives identified by each project address the need to go to a higher annual flight rate.